For Reference

NOT TO BE TAKEN FROM THIS ROOM

Library of the University of Alberta, Edmonton, Alberta

Murray, James Allan

The influence of the protein content of the ration and other factors, on carcass quality in the bacon hog. 1935.

Ex Libris
Universitatis
Albertaensis



Digitized by the Internet Archive
in 2017 with funding from
University of Alberta Libraries

https://archive.org/details/murray1935

935
+28

THE INFLUENCE OF THE PROTEIN CONTENT OF THE RATION, AND OTHER FACTORS, ON CARCASS QUALITY IN THE BACON HOG.

By James Allan Murray

A THESIS

submitted to the Department of Animal Husbandry of the University of Alberta in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

University of Alberta

June 1, 1935.

Preface.

This thesis is based upon a number of experiments conducted at the University of Alberta during the summer of 1934 and the winter of 1934-35.

I wish to register my appreciation to Professor J. P. Sackville, Head of the Department of Animal Husbandry, University of Alberta, for placing the facilities of his Department at my disposal. Dr. Revell and Dr. Shaner, of the Department of Anatomy, University of Alberta, have allowed me the use of their laboratory and equipment which, along with their advice and suggestions, rendered valuable assistance in the preparation of the histological materials used in the earlier part of this work. For these I wish to tender my deepest gratitude and thanks. The co-operation of the Swift Canadian Company, Edmonton, made it possible to obtain the materials and measurements so necessary in this thesis, and for this assistance I am very grateful. I am deeply indebted to Dr. R. D. Sinclair, Professor of Animal Husbandry, at the University of Alberta, who initiated the experiments reported here and who through suggestions, aid and kindly criticisms rendered an invaluable service not only in carrying out the projects but also in preparing the manuscript.

The experiments reported in this thesis were made possible by a Grant from the Carnegie Foundation to Dr. R. D. Sinclair, under whose supervision the investigations were conducted.



TABLE OF CONTENTS.

Page.

INTRODUCTION..... 1

OUTLINE OF PREVIOUS, CLOSELY RELATED INVESTIGATIONS:

The Importance of Protein in Nutrition. 4
The Relation of Protein to Growth..... 6
The Effect of Food Protein on Body Protein..... 8
Growth and Fattening in the Pig.....10
Carcass Quality Defined.....11
Variations in Carcass Quality.....12

OBJECTS OF UNIVERSITY OF ALBERTA EXPERIMENTS..... 17

METHODS OF EXPERIMENT..... 17

EXPERIMENT I 22

EXPERIMENT II 37

EXPERIMENT III 46

A STUDY OF THE CARCASS DATA ON A LITTER BASIS..... 62

A FURTHER STUDY OF CARCASS DATA..... 68

SUMMARY OF EXPERIMENTS AND ANALYSES..... 76

CONCLUSIONS..... 81

BIBLIOGRAPHY..... 84

THE INFLUENCE OF THE PROTEIN CONTENT OF THE RATION, AND OTHER FACTORS, ON CARCASS QUALITY IN THE BACON HOG.

Canada, at the present time, stands second with respect to the volume of pork products that are exported from any one country to Great Britain; Denmark holds first place. The British Market is very discriminating and any country which hopes to maintain a satisfactory status thereon must supply products of the highest quality.

While Canadian bacon occupies second position in the matter of volume it unfortunately rates much lower in market value and is actually the lowest priced bacon sold in Great Britain. Since price levels on such a market are strictly indicative of quality, it is clear that the export product derived from Canadian hogs is on the average of an indifferent quality.

Those who have made comparisons of Canadian bacon with that from countries such as Denmark, whose product is most highly regarded, recognize that there are certain definite weaknesses in the Canadian article. These defects have been pointed out by various British importers from time to time so that Canadian producers and processors have reason to be informed regarding the general problems.

The bulk of the pork products which is shipped to Great Britain goes forward in the form of what are known as "Wiltshire

Sides". These sides comprise one entire half of the carcass of a bacon hog trimmed according to standard procedure. This side, therefore, includes shoulder, middle piece and ham, and in the process of distribution in British Shops may be cut into these sections and further subdivided.

In general the complaints laid against the Canadian Wiltshire Sides, as compared for example with the Danish Sides are as follows:

1. The lack of length in the middle piece, which portion sells at a higher price than the two end cuts.
2. An excessive weight in the shoulder end. This is the lowest price part of the side.
3. A lack of development of ham.
4. The entire side shows too high a percentage of fat in proportion to lean.

Expressing the problem in the reverse order, Danish Wiltshire Sides show more length of middle piece, carry a lighter shoulder with a heavier ham and in general contain a high percentage of lean meat to fat.

Various reasons have been advanced for the low average quality of Canadian bacon. It is generally recognized that the preponderance of breeding stock of non-bacon type is a major contributing factor. However in addition, a number of the feeding and management practices have been questioned as to their effect upon the product yielded after slaughter. The prevailing system of out-door pig raising which encourages unlimited exercise on the part of the growing pig has been compared with the Danish system of close confinement during the growing and fattening

stages. It has been suggested by British importers that this system of management leads to the development of a heavy shoulder and what is regarded in the trade as "tough" bacon.

It has been argued that the comparatively high proportion of muscle or lean meat in the Danish Wiltshire Sides is due to the widespread use of high protein rations. It is common practice in Denmark to feed skim-milk in liberal volume to the growing pigs and in addition fish meal at the rate of about 10% of the ration. There is no doubt that the average Danish pig ration contains a significantly higher percentage of protein than the average ration being fed to Canadian bacon hogs. The question which immediately arises is, "Can the amount and percentage of lean in the carcass be influenced by the percentage of protein fed in the ration"? This question touches upon a very vital issue in connection with the production of bacon hogs in Canada because under average conditions dairy by-products are lacking and other protein rich feeds are not commonly used. If a protein deficiency in the ration leads to the development of a carcass containing an excess amount of fat our possibilities in connection with high quality production may be limited and on the other hand if heavier protein feeding will stimulate the production of a "lean" carcass then our feeding practices should be subjected to revision.

With a view to throwing some light on a number of the questions which have been raised regarding the influence of certain feeding and management practices on the quality of carcass

in bacon hogs, some experiments were conducted at the University of Alberta during the summer of 1934 and the winter of 1934-35. It will be the purpose of the discussion which follows to present the results of these experiments and at the same time to present the results of an analysis of data obtained from fairly extensive carcass measurements in the hope that some correlations may be established between certain major factors which together constitute carcass quality.

Before presenting the results of these experiments, however, it would seem well to briefly present the findings of more or less closely related investigations.

THE IMPORTANCE OF PROTEIN IN NUTRITION.

In view of the high protein content of all vital tissues and organs in the animal body, the importance of the protein fraction of animal rations has long been recognized. Armsby (1) points this out, and at the same time quotes the reasons for his statement by saying:

> "The larger share of the organic matter in the animal body aside from fat consists of substances belonging to the group known as proteins. These are of the greatest biological importance in that they form the basis of cytoplasm and nucleus of the living cell".

McCollum (2) Starling (3) and numerous other authorities have stated the same thing. Arising from this knowledge has come the realization that proteins are a necessary ingredient in all animal diets, whether the ultimate object of these be for growth, fattening or maintenance. Cameron (4) considers proteins

to be the most important of the three classes of food-stuffs, proteins, carbohydrates and fats, his reasons for this belief being that carnivorous animals at any rate can subsist on a diet of protein without fat or carbohydrate and can form from protein the fat and carbohydrate they require.Lusk (5) makes a special point of the "constant need of protein" and in his conclusion corroborates the views already expressed. Armsby (1) Chittenden (6) Smith (7) McCollum (2) and other leading authorities on nutrition, while their views on the quantities of this ingredient necessary vary in many cases, are all of the opinion that protein is necessary for the proper development and functioning of the animal body.

The pioneer workers on the problem of protein requirements centred their interest very largely upon the quantitative aspect of the question. The amount of protein necessary for normal metabolism was regarded as the major issue. More recently, however, the qualitative phase of the problem has assumed a prominent position and it is now recognized that the biological value of the protein in a ration must be given careful consideration. A protein must contain, in its molecular structure, at least one amino acid (4). Osborne and Mendel were among the first workers to determine the value of these amino acids in nutrition. Since their time it has been found as Starling (3) Henry & Morrison (8) Bodansky (9) Mendel (10) McCollum (2) and others have pointed out, that the chief value of a protein insofar as it is to be used for nutritional purposes, depends primarily upon its amino acid content. Henry & Morrison (8) have stated that

in the formation of protein tissue of the animal body all the various amino acids are required, hence for normal growth the proteins in the food must supply all of these necessary amino acids. Since the initial work was carried out along this line it has been found (1) that the amino acids themselves vary in value, this depending upon their ability to carry out biological processes. In any case it may be seen that before any discussion on the effect of various proteins on growth or development may be undertaken, the quality factor must be considered.

THE RELATION OF PROTEIN TO GROWTH.

It has already been stated that protein is necessary for both growth and maintenance. The animals in which we are interested in this study are those which are immature when slaughtered. This is in accordance with the assumption of Dietrich (12) who considers a pig 18 months of age mature. It also follows the reasoning of Armsby (1) where he speaks of maturity in a commercial sense, dictating an animal as mature, when it is ready to be slaughtered for market. Following either of these arbitrary assumptions, growth, rather than maintenance is the biological process with which one is mainly concerned.

The physiological phenomena of growth may be defined as the increase of the nitrogenous structural elements of the body. This is more specific than using an increase in size as a comparative growth criteria in that, as Armsby (1) points out, growth in this sense may occur on a ration barely sufficient or

insufficient for weight maintenance; which would mean that growth may be masked by a loss of fat from the body. This is a condition which under ordinary circumstances would not exist. Therefore, we have to deal primarily with the normal development of the protein in the animal body as it proceeds from birth to maturity. According to determinations made by Wilson, the body of an eight day old pig is about 80% water and 18% protein. Using these results and a number of others compounded by different workers, Armsby (1) formulates the broad conclusion that the rate of growth of protein is relatively high in the new born individual, it decreases rapidly at first and then more slowly, tending then to become asymptotic to the zero line. The results obtained by Hammond (13) in the study of the growth and development of sheep, follow this conclusion very closely.

We have seen that growth or the development of protein tissue in the body cannot take place unless protein in some form has been added to the diet. There must be some connection between the graph of protein development as drawn by Armsby and the feed to which the animal is subject. Indeed Armsby (1) continuing his discussion remarks that in immature fattening animals any excess of protein that is added above that required for maintenance is used for growth and development. Smith (7) also verifies this conclusion by stating, after comparing the nitrogen excreted as a result of protein metabolism from mature and immature animals that nitrogenous equilibrium cannot exist in young growing animals, meaning that some of the nitrogen from proteins ingested has been

utilized in the building up of body tissue. Chaney & Ahlborn (14) propound this less technically in saying that at those times in life when growth occurs, the protein requirement for building is high.

> "Feeds rich in protein tend to build up strong muscular frames and large individuals with ample blood and fully developed internal organs".

This comprised one of the results of an experiment carried on by Henry (15) at Wisconsin, in which was compared a ration containing shorts and bran as a source of protein, with one in which corn was fed alone. From this it is seen that some relation does exist between the initial protein development within the body and the protein that is supplied during that period.

THE EFFECT OF FOOD PROTEIN ON BODY PROTEIN.

The question now arises as to whether the extent or the character of this development is in any way affected by the quantity or quality of the protein fed. Since there is such a definite relationship between the protein ingested and the growth of muscle or lean meat, it would seem probable that an insufficient supply of these nitrogenous compounds would exert a very marked effect upon the final product of growth. Shaw (16) states that shortage of protein affects materially the early growth of the animal, but has little or no effect during the later stages of growth. Speaking over a wider range of time, Swanson (17) finds that pigs fed on rations decidedly deficient in protein had a very restricted growth, the composition of the

body in this case showing generally a low fat and a high water content. While there are few workers who have made actual chemical analyses of the animal body as has Swanson, a number have made visual comparisons - with respect to the fat content - following a low protein diet, and their conclusions vary somewhat with those just quoted. Curtiss & Craig (18) found that feeding a wide ration, or one high in carbonaceous material resulted in a carcass containing excess fat, whereas a narrower ration produced a carcass containing more or less meat or muscle. Sheldon (19) Duggar (20) and Forbes et al (21) have arrived at the same conclusion. Joseph (22) sums this up by saying that when the supply of protein is deficient in either quality or quantity the amount of body protein is directly affected.

Under conditions where there is an excess of protein added, however, we find results which are not parallel to those just mentioned. Swanson (17) states definitely that a large amount of protein fed will not produce a pig with a high protein content. The effect being rather to produce a rapid growth as compared to that of an animal on a lower plane of protein nutrition; in both cases the final protein content will be the same. Joseph (22) found that a variation of from .32 to .95 lbs. per c'w't live weight per day of protein consumed had no effect upon the nitrogenous product. Armsby (1) in reviewing the results of a number of experiments dealing with the effect of high protein in the diet finds that while the results show that there is some advantage resultant of feeding high protein, it is expressed in

total body gains, which does not necessarily mean a high comparative protein gain within the body. The actual condition might be that, the excess of protein supplied over and above that required for growth and maintenance is being broken down within the body and used either as an immediate source of energy or to build up reserve energy in the form of fat. In any case, it would appear that an increase of protein added to the diet has not been found to result in an increase of protein tissue in the animal body.

GROWTH AND FATTENING IN THE PIG.

Judging from what has been said, muscle development and fattening while they go on simultaneously,are two distinct processes. Armsby (1) considers them to be separate but both involved in the process of growth, the latter being used in the wider sense of entire bodily development. He suggests that fattening should be timed so that it will be completed when the rate of gain of lean meat ceases to be profitable. In discussing the influence of feeds on the type of market hogs, Rothwell (23) says that one must allow for the maximum muscle and bone development before laying on too much fat. Hammond (53) certainly deals with these as two distinct processes, emphasizing at all times the importance of considering the proportions of lean to fat at different stages of development. He suggests that due to body development it might be advisable to grow pigs rapidly at first, while muscle is developing, and finish them more slowly as fat

develops. In any discussion, therefore, where the quality of the carcass is the subject, not only must the lean meat or muscle and its development be considered, but also the fat and its relation to the nitrogenous tissues.

CARCASS QUALITY DEFINED.

In connection with the discussion which follows, the general term "carcass quality" will be used quite frequently. It would then seem advisable at this time, to define this term, at least from the point of view of common usage. The term "carcass quality" as applied to the bacon hog carcass refers in the broad sense to the general dimensions and proportions of the carcass, together with the amount of fat which it contains in proportion to the lean meat or muscle. The Canadian standard of carcass quality is set by the demands of the British market. Carcasses of the highest quality are long of side, carrying a light weight shoulder and a fully developed ham. The external covering of fat should be comparatively light and of uniform thickness throughout, so that a cross-section through the carcass will have a general appearance of leanness rather than of excess fat. The term "carcass quality" also embraces variations in the composition of the fat and differences in the histology of muscle bundles.

VARIATIONS IN CARCASS QUALITY

Baethge (24) in a number of experiments found that the rates of gain of individuals showed a great variation, which could be traced to hereditary factors. In a study of the carcasses of the same animals he concluded that the quality also seemed to be linked up with breeding. In fact, as a general conclusion he states that:

> "the best reared pigs gave the driest carcasses, richest in fat; the worst reared pigs gave the worst quality carcass".

This same conclusion has been intimated by Joseph (22) in his work at Illinois. On the other hand in later work at Illinois, it was found that the length of the body varied directly as the protein fed.(27) The same conclusion was arrived at by Schutte & Murray (25). When feeding varying levels of barley in the ration, they found that when barley was fed to the extent of 45% of the ration, there were produced a greater number of higher grade, longer and firmer carcasses. In the Illinois report just quoted, it was also found that the lot fed on a low protein diet showed a percentage of ham and shoulder that was greater than the percentage side, as compared to the other lots in which these two were found to be about equal. The results obtained in these latter cases tend to show that the actual anatomical make-up of the animal may be changed as a result of the ration fed.

The quality of fat with regard to its firmness and the

relation that factor bears to the fat fed was thoroughly investigated some years ago, and it was found that feeds had a very marked effect upon the firmness of the fat produced in the animal body. However, very little has been done to study the physiological deposition of fat resulting from varying feeds, or the relation it bears to other parts of the carcass when varying factors are imposed. As an illustration, at Indiana (26) it was found that the greater the finish the lower was the percentage cut of ham and loin and the higher the percentage of belly bacon. IT is a relation of this type in which we are interested when studying hog carcasses, in that such qualities as finish and length of side may be at least roughly assessed when viewing the live animal.

Hammond (13) has conducted carcass studies with sheep and hogs, interpreting his results as the relative proportions of the body tissues - fat, muscle, bone and tendon. In these discussions he brings out the point that the development of the animal body is backwards; that is, the neck and shoulders of a young animal are always large in proportion to the rest of the body, as development proceeds, it does so in a posterior direction. First the length increases and finally the depth. While there is no doubt that age and its relation to bodily development is of vital importance, nevertheless due to the standardization of market weights in various countries the age factor, and to a greater degree the weight factor, are fairly definitely eliminated as variables. This means that any studies which are made at present upon the relation of quality factors

of the carcass are based upon weights and ages which deviate only slightly from the standards and the variability of which are not sufficient to warrant their use as a basis for determination.

A phase of this carcass development which has received considerable attention lately has been the relative size of the shoulders in comparison with the rest of the body. Emmett & Grindley (27) have found that the weight of the shoulder is about four pounds greater than the weight of the ham. Since the hindquarter contains much less bone and thus has a higher selling value than the forequarters, such a weight ratio of these two parts is of great importance, particularly to the packers and processors. The ideal conformation would then be a carcass in which the shoulders and hams were at least equal in weight. According to Hammond's theory on body development, such a condition should eventually develop, but it does not seem to do so, at least within the age ranges to which we are limited. A point has been brought up which intimates that exercise might in some way influence the development of the shoulder. That is, with an increase amount of exercise there might be an increased muscular development, the net result being a shoulder which was relatively large when compared with the rest of the carcass.

In an experiment conducted to determine the effects of exercise upon both dogs and swine, Kuibs & Berberich (28) found that under conditions of increased exercise there was an increase in the size of muscles. However, Hammond points out that long distance runners do not develop large calf muscles. These two statements are contradictory, but in either case what manner

of determination is to be used as a means of specifying either an increase in size, or a maintenance of size. It is pointed out that fattening tends to increase the size of muscle, due to the marbling which occurs as a result of this process.(53) However, in the participation of exercise, energy is expended, which causes a utilization of fat; hence, these two conditions if imposed at the same time might tend to offset each other. For this reason the actual size of the muscle as a whole would not be a very accurate criteria for means of comparison. The muscle fibres, or those units which go to make up the muscle bundles, contain no fat (40) and, hence, would be a more satisfactory integral to use for determination.

Hammond (13) in presenting the results of his growth studies with sheep has made a very complete review on the subject of muscle fibre development and has found on reviewing the literature that results are very contradictory. He quotes Morpurgo (33) Halban (34) Schiefferdecker (35) and Hauck (36) to the effect that exercise does increase the size of the muscle fibre. Schafer (37) and Prenant (38) also quoted by Hammond (13) claim that under such conditions there is an increase in the number of fibres rather than the diameter of those already formed. The results on the effect of nutrition upon muscle fibre size are of a slightly more positive nature and tend to show generally that the plane of nutrition has a direct bearing upon the development of muscle fibres.

Robertson & Baker (40) found that muscle fibres showed a definite relation in size to the adiposity of the animals. From.

this it may be seen that in interpreting the results obtained in any muscle fibre measurements, both exercise and nutrition must be considered.

Leighton & Douglas (39), in discussing the effects of exercise, bring up the point that exercise increases the amount of connective tissue holding the muscle fibres together. Following this statement they relate the connective tissue content with tenderness, qualifying this by pointing out that the meat around the joints where there is a large amount of this tissue, is tough. That is, that the tenderest meat is that which has the lowest percentage of connective tissue. Hammond (13) quotes Isaak (41) to the effect that the thickness of muscle fibre does not influence tenderness, but that the latter may be due to the amount of connective tissue or to a difference in the structure of the muscle fibre. Tenderness is a difficult quality to estimate and compare, at least by any methods devised up to the present. Meat dynamometers have been used in the United States and eating trials have been conducted on numerous occasions but neither of these methods have proven to be a very successful means of comparison. However, if we use the connective tissue content and the muscle fibre diameter as a criteria for tenderness, as has been pointed out, there appears to be a relationship existing between exercise and tenderness which may be computed in terms of muscle fibre development and connective tissue development.

Having reviewed briefly what have been found to be some of the important factors in the determination of carcass quality, it would now seem in order to proceed with a discussion of the

experiments conducted at the University of Alberta and which form the basis for this thesis.

EXPERIMENTS CONDUCTED AT THE UNIVERSITY OF ALBERTA.

The experiments carried on at the University of Alberta during the summer of 1934 and the winter of 1934-35 were conducted with the following objects in view:

1. To study the effect of exercise and particularly "rooting" on the development of shoulder and on general carcass quality in the bacon hog.
2. To compare high and low planes of nutrition when applied to inside and outside feeding and to note the effect of these factors on the development of shoulder and general carcass quality.
3. To study the effects of feeding several mixed protein-mineral supplements in the ration for growing pigs, upon carcass quality generally, with special consideration as to the quantity of protein produced.
4. To note the effect of varying the level of protein in the ration on the development of lean in the carcass of the bacon hog.
5. To determine any co-relations which may exist between the proportion of lean meat in the side of a carcass and other factors of importance in the estimation of carcass quality.

Methods of the Experiments.

The objects just outlined indicate that the experiments consist very largely of a study of the carcasses yielded by pigs subjected to varying conditions,as to rations and management. All the carcasses studied were treated and measured in the same manner.

When the experimental animals reached standard market weights, they were trucked to the Swift Canadian Packing Plant, where they were graded, slaughtered and dressed according to regular abattoir routine. For a period of from 36 - 48 hours, the carcasses were chilled at a temperature ranging from 28°F - 34°F; following which they were measured and cut according to Dominion Government Advanced Registry standards. Hot and cold dressed weights were recorded.

In all cases the right side of the carcass was used for making determinations. Records were made of the following measurements: (a) length - distance from the point of the first rib to the point of the hip bone, (b) shoulder fat, (c) back fat, (d) loin fat, (e) maximum belly, (f) minimum belly, (g) width of heart girth, and (h) width at flank. Following this, the half of the carcass being used was cut into three sections; the weights of these were doubled to represent the corresponding part of the entire carcass, and recorded.

(a) Shoulder. That portion anterior to a cut made parallel to the width of the side, between the second and third rib.

(b) Ham. The cut was made two inches in front of the hip bone. The portion posterior to this was recorded as ham. The feet on both the front and hind legs were removed at knees and hocks.

(c) Middle. That part remaining after shoulder and ham was removed. The portion designated as middle had the backbone and tenderloin removed, following which samples were taken to be used in making further laboratory studies.

As has been stated, previous to cutting, the carcasses remained in the cooler for a period ranging between 36 and 48

hours, so that while the tissue was not fresh, time and conditions were such that it had not had time to deteriorate to any extent.

The samples were taken in all cases from the right side of the carcass and immediately posterior to the last rib. Since these portions would average about two inches in thickness they represented a part of the side cut parallel to the transverse subcostal line of the carcass and including on the ventral line the last thoracic vertebra. Therefore, there was illustrated the covering of fat over the back and belly , the "eye of lean" or longissimus dorsi muscle and also the external oblique, internal oblique, transverse abdominus and a small portion of the rectus abdominus muscles. The inter-muscular fat was also clearly defined. These samples were immediately frozen and left in this condition until they were needed.

It was found that on freezing, the outer surfaces tended to discolor slightly and to lose their original form, thus making it difficult to obtain an exact replica. Hence, before any work was carried out on these, they were allowed to thaw partially and were then split in two. The surfaces exposed in this way were normal in color and in good structural condition.

Tracings were made of these samples on small panes of ordinary glass with the use of a glass pencil. Following this, by mounting the panes over a light, it was possible to transcribe the tracings through and on to heavy white paper. Area measurements were made from these latter copies.

A planimeter was used to make all measurements. The total area of the entire sample was taken, and individual determinations on all the muscles were made. From these figures the percentage of lean and fat and also the percentage of the whole, or of any of the individual muscles could be obtained. In these studies, the percentage of the "eye of lean" or longissimus dorsi muscle and the external oblique muscle as well as the percentage total lean were tabulated.

Histological Methods and Procedure.

Histological examinations were made on some of the shoulder tissue of the animals in Experiment No. I. Small cubes were taken from the infraspinatus muscle of the right shoulder when it was exposed following the cutting of the side as has been outlined. Two samples were fixed for histological study, one in Zenker's solution, another in 10% Formalin solution. These were embedded in paraffin and sectioned at 11 microns thickness. A third sample was macerated in 20% nitric acid for about 24 hours, following which it was washed in a saturated solution of potassium acetate and then allowed to remain in glycerine.

The paraffin sections were stained with Mallory's connective tissue stain, Van Gieson's stain and haematoxylin-eosin, in an endeavor to differentiate and, if possible, compare the relative amounts of connective tissue present in the various samples. The tissue which had been macerated was used in making measurements of the muscle fibre diameters. Two slides, mounted

in glycerine, were prepared from each sample, one hundred measurements were made from each slide. From these, the average diameter of the muscle fibres was calculated.

Weights and Feed Consumption.

The pigs were weighed on three consecutive days at the beginning and the end of the experiment, the averages of these being used as the intial and final weights respectively. Individual weights were taken every 14 days throughout the feeding period. The feed consumed during the experiment was recorded.

EXPERIMENT NO. I (Summer 1934)

The Influence of Exercise and "Rooting" on Size of Shoulder and Carcass Quality.

Pigs Used:

In this experiment three groups, each consisting of six individuals, were used. The groups were selected on the "litter basis", as uniform a distribution as possible being made with regard to size, age, sex, type and general thrift. There were allotted to each group, 4 Yorkshire-Tamworth crosses, 1 purebred Yorkshire and 1 purebred Tamworth. The average weight of all the pigs was approximately 47.5 pounds, and the average age 45.1 days.

Method of Housing:

One lot of the three was fed inside during the entire fattening period. These were confined in the shed piggery of the University Farm, in a pen 10' x 12'. This latter is floored with concrete and supplied with a 7'x8' wooden sleeping platform. The pigs were bedded in straw which was renewed every other day. There was no access to an outside runway.

The other two lots were run outside during the entire feeding period. Each being on a plot about 30' x 100', and having access to an "A" type colony house 6' x 8', bedded with straw.

Arrangement of Groups:

The following plan was adopted in arranging the groups:

Group I : Inside feeding - full grain feed.

Group II : Outside feeding - full grain feed.

Group III : Outside feeding - limited grain feed.

Method of Feeding:

Full and hand-feeding was practiced in the case of Lots I and II. Lot III was hand-fed at the rate of 3 pounds of grain per 100 pounds live weight, daily. This latter group, due to insufficient feed being allowed, made poor gains, and it was found necessary to supply them with a full grain ration for the last six weeks in order to bring them up to market weight. All the feed consumed for each lot was recorded.

Lots II and III were given access to a mixed cereal pasture from the outset of the experiment.

Rations Fed:

Grain: The grain mixture used in this experiment was as follows:

	Beginning to 130 lbs.	130 lbs. to finish.
Ground barley (3 C.W.)	40	60
Ground oats (3 C.W.)	40	20
Ground wheat (3-5.N)	20	20

Protein Supplement: Tankage (50% protein) was fed as a supplement to the grain ration at the following rates:

Beginning to 130 lbs: 10%
130 lbs. to finish : 8%

Cod Liver Oil: Lot I was fed 1 pound cod liver oil per 100 pounds grain during the first period, that is, until the pigs attained a weight of 130 pounds. No cod liver oil was given to the two lots fed outside.

Salt: 1 pound of salt was added to each 100 pounds of the grain and tankage mixture in all lots.

Discussion of Ration & Method of Feeding:

The grains fed, as may be seen from the grades, were of good quality and were in all cases mixed in the ground form. Tankage was the only protein supplement fed; while it alone is probably not as good as a mixed supplement, nevertheless it has been found to contain sufficient of the nitrogenous and mineral elements to provide normal growth and development.

The method of feeding as outlined above was selected for two reasons. The first was to vary the amount of exercise which the animal could and would take. That is, the lot fed inside, not having access to any runway would get a minimum amount of exercise; the lot fed outside on full feed would "root" and run depending upon the inclination. The third group, however, being on a limited ration and, therefore, in a condition of semi-hunger were induced to take a maximum amount of exercise and give full play to the "rooting" instinct.

The second reason for following the method of feeding outlined was to study the effect that limited feeding as compared to full feeding would have upon the development of fat and lean in the carcass.

RESULTS OF EXPERIMENT NO. I

The average daily gain of the three lots is summarized in the following table:

Table I : Average Daily Gains:

	Lot I (Inside full fed)	Lot II (Outside full fed)	Lot III (Outside full fed)
Av. Initial wt:	47.75 lbs.	47.0 lbs.	48.33 lbs.
No. days on Expt.	111	119.5	167.
Av. Final Wt:	217.33 lbs.	220.17 lbs.	216.67 lbs.
Av. Daily Gain:	1.53 lbs.	1.44 lbs.	1.01 lbs.

It may be seen from these figures that there was a considerable variation in the rate of growth in the three lots; Lot II, which was full fed, on pasture, showing a decline of .09 pounds per day as compared to Lot I which was full fed inside, but an increase of .43 pounds per day as compared to Lot III, which received only half-feed on pasture. The difference between Lot II and Lot I, therefore, would appear to be due to the energy expended in the form of exercise in the case of the former. That is, some of the feed which was used in the first lot to form body tissue and thus demonstrated as an increase in gain, was used in the case of the second lot as a source of energy and thus was not accounted for in bodily gains. Lot II and Lot III were both fed on pasture. It may be seen that the latter group was receiving insufficient food for full development even after allowing for an additional

energy requirement resulting from this low plane of nutrition and the increased exercise which might be expected to be the result.

Following 111 days of feeding, at which time all the animals in Lot I had reached market weight, there was very little apparent difference in the animals in the first two lots other than a clearer and somewhat whiter appearance of those fed inside. At this stage, however, the individuals in Lot III showed a definite lack of development and thrift. Nevertheless, in spite of this retarded growth and general unthrifty appearance at this stage, after a period of full feeding in which remarkable gains were made, they assumed market weight with an apparent condition quite similar to those animals in Lot II.

Feed Requirement for Growth:

The following table shows the average daily feed consumption, and the feed requirement for 100 pounds gain in live weight.

Table II: Feed Required for Growth
(All weights in Pounds)

Lot No.	Av. Daily Feed Consumption	Feed Req'd for 100 lbs. Gain	
		Grain	Protein
I : Inside full fed	5.56	324.86	32.01
II: Outside " "	5.93	368.60	36.28
III: " ½ fed	4.08	364.66	35.48

The ratio of the feed consumed daily in the three lots corresponds very closely with the ratio of daily gains in the same lots. The difference of .37 pounds, between Lots I and II is of relatively little significance, whereas Lot III, as would be expected from the method of feeding practiced, showed a considerably lower daily feed consumption. The feed required to put on 100 pounds of live weight gain, however, shows some variation from this ratio. Lot I, fed inside with very limited exercise required 354.87 pounds of grain and protein to put on 100 pounds of live weight gain. Lots II and III, however, required 404.88 pounds and 400.14 pounds, respectively, of grain and protein to make the same gains.

The result, therefore, of feeding Lots II and III on pasture, as compared with Lot I fed inside, was an increased feed requirement of 50.01 pounds in the case of Lot II, and 45.27 pounds in the case of Lot III, per 100 pounds increase in live weight. As has been pointed out earlier, one difference resulting from these two methods of feeding, is in the amount of exercise which the animals take. Therefore, this wide variation in feed requirement could, at least in part, be accounted for as the increase energy demands of those animals fed under conditions where any amount of exercise could be taken.

A comparison of the feed requirements of Lot II and Lot III show that the third lot required 4.74 pounds less feed to put on 100 pounds gain than did the second lot. It was stated earlier that for the major part of the experiment Lot III received about

one-half the amount of feed that Lot II consumed per day, but that due to the lack of development this third lot was placed on full feed for the last few weeks, following which they obtained market weight in as good condition as did the second lot.

Reference to Table I shows that Lot III was in the feed lot 47.5 days longer than was Lot II, and showed a correspondingly lower average daily gain. This would indicate that normal growth and development took place in Lot III, even when the feed was restricted to one-half the amount the animals would eat, and that the final weight and condition was obtained after a somewhat longer time than was the case in the other lot, but with a slightly lower feed requirement.

The Effect of Exercise and Limited Feeding on Carcass Quality.

Mention has been made of a number of the measurements which are used as a criteria for the determination of carcass quality. The depth of shoulder fat, back fat and loin fat are measurements of the thickness of fat along the dorsal line at the points which the names indicate. The measurements of maximum and minimum "belly" were made at points in the centre portion of the carcass at strategic points in relation to commercial value. These latter are of importance in that they indicate not only the thickness of the side of bacon which will result from the carcass, but also the amount of trimming which has to be done to make the thickness consistent throughout the side.

TABLE III: Measurements and Percentage of the Cuts of Carcasses.

	Lot I (Inside full feed) (ins)	Lot II (Outside full feed) (ins)	Lot III (Outside half feed) (ins)
Average length of carcass:	30.25	30.00	30.25
% Shoulder of Carcass:	27.72	28.10	28.28
% Ham " " :	22.07	22.88	23.19
Av. Depth of Shoulder Fat:	1.96	1.83	1.75
" " " Back Fat :	1.29	1.23	1.21
" " " Loin Fat :	1.52	1.35	1.44
Av. Min. Belly Thickness:	1.03	1.05	.93
" Max. " " :	1.88	1.90	1.94

A survey of the data recorded in Table III shows that there were no marked differences in the quality of the carcasses within the three groups. It will be noted, however, that the carcasses from Lot I showed slightly heavier finish than those from the other two groups. This is indicated by the fat measurements along the back and also by the fact that the minimum belly thickness (measurement at flank) is somewhat less in Lot III than it is in Lots I and II. The different methods of feeding and management employed did not result in shoulders which showed any significant variation as to percentage of the whole carcass. It would appear that unlimited exercise and opportunity for rooting did not exert any influence on the development of this portion of the carcass.

It is of interest that there is no difference in the length of side as between Lots I and III. This bears out the findings of Sinclair and Sackville (42) and is in disagreement

With those of Rothwell (23) who states that:

> "any system of feeding a bacon hog that tends toward the too early laying on of fat and prevents the maximum growth of bone and muscle during the first four months tends towards the development of a shorter, thicker carcass".

Grading of the Carcasses and "Bellies"

The animals were graded by Government Graders before they were slaughtered and designated as "selects" and "bacons". The former of these two is the higher grade and includes animals of the optimum length and finish. The grade of "bacon" applies to animals somewhat shorter and showing from external appearance a somewhat heavier finish. The carcasses were graded by a packing plant carcass expert. The "leanest lean" carcasses are those which showed the optimum covering of fat, ranging from 1" to 1½". "Lean" carcasses had a covering of from 1½" to 2". The "belly" grading was an entirely arbitrary arrangement made by the packing plant expert and referred to the thickness of the belly and also the general proportions of the side. There are three "belly" grades indicated, excellent, good and fair.

TABLE IV: Carcass and "Belly" Grades.

	Lot I (Inside full feed)	Lot II (Outside full feed)	Lot III (Outside half feed)
Live Grading - Selects	5	4	4
Bacons	1	2	2
Carcass Grades -			
Leanest Lean	6	4	4
Lean	-	2	2
Belly Grades -			
No. Excellent	3	5	4
No. Good	3	1	1
No. Fair	-	-	1

The gradings presented in Table IV suggest that there was little difference in the appearance of the live hogs in the various lots when marketed. It is to be noted, however, that only one "bacon" was graded out of Lot I as compared with two in each of the other groups. The live grades tend to suggest rather a heavier finish in Lots II and III than in Lot I, a condition which was not indicated by the fat measurements shown in Table III. The "belly" grading would tend to show that the carcasses in Lot III were somewhat deficient in thickness of fleshing in the flank region. One carcass in the group obtained a rating of "fair". This grading is in line with the measurements shown in Table III. It will be noted that the average minimum belly thickness in Lot III was .93 inches as compared with 1.03 inches in Lot I.

Detailed Carcass Measurements.

Detailed measurements, by means of a planimeter, were made on sections secured from each carcass. The total area of the entire section was recorded. Following this, measurements were made on the total lean in the section, special tabulations being made of the area of the longissimus dorsi muscle, or the "eye of lean", and also the external oblique muscle or the "streak muscle" as it has been designated in the following table . The results of these detailed measurements are recorded in the following table.

TABLE V: Detailed Carcass Measurements.

	Lot I (Inside full feed)	Lot II (Outside full feed)	Lot III (Outside half feed)
Av. Total area of cross-sections (sq.in.)	28.20	25.70	25.85
% Lean in cross-sections	31.88	35.09	38.81
Av. Area of "eye of lean" (sq. in.)	3.95	3.90	4.57
Av. Area of "streak muscle" (sq.in.)	1.49	1.63	1.67

The data presented in Table V introduces some factors of quality of the carcasses which were not presented in the other tables. The total area of the cross sections vary somewhat. Those in Lot I are larger than those in either of the other two lots, as might be expected, following a review of the fat measurements tabulated in Table I. The percentages of

lean in the cross sections show a marked gradation. Lot I, due to the increased finish, shows the lowest percentage of lean, and also has a small "eye of lean" and "streak muscle", as compared with Lot III. The sections from Lot II contained a higher percentage of lean than those in Lot I. Since there was no difference in the size of the "eye of lean" of these two lots, and only a small difference in the "streak muscle", this increase in lean must have been quite general throughout the section. Lot III is the opposite extreme to Lot I. The percentage of lean in the sections was decidedly higher than in either of the other two groups. The "eye of lean" averaged .62 and .67 sq. in. larger than in the case of Lot I and Lot II, respectively. The "streak muscle" was also somewhat larger in this group than it was in Lot I, although it was practically the same as in Lot II.

Reference to Table I shows that there was a difference in the length of time in which these three lots were on experiment. The percentage of lean in the carcass increased with age but not proportionally. According to the data, the lean percentage of Lot II increased over that of Lot I in eight and one-half days, an amount equal to the increase percentage put on by Lot III over Lot II in 47.5 days. From this it would appear that the age factor alone was not entirely responsible for the increased lean in the cross section. Judging from the gradual increase in the muscle tissue, the amount of exercise to which the animals were subject might have been responsible for this gradation. However, according to the figures, there was an

increase in size of the "eye of lean" in the carcasses in Lot III, but none in the other two groups. There was an increase in the "streak muscle" of Lot II and Lot III over that of Lot I, but no increase in this muscle as between Lot III and Lot II. Hence, while the exercise may have had a tendency to increase the lean meat, it would appear that increasing age was a more important factor. However, neither one of these alone was responsible for the additional muscle tissue formed.

The increase in the size of the "eye of lean" in Lot III as compared to the other two lots might also be due to these factors of age and exercise. In the case of the latter, however, it might be expected that if exercise had any effect upon the development of this muscle it would show an increase in size in Lot II as compared to Lot I. Such, however, was not the case. The age factor, when considered in relation to the muscular development introduces the theory developed by Hammond (13) which indicates bodily development in a posterior direction. If this is applicable, the development of the "eye of lean" takes place at some time following the 120 day feeding period. If this development can be accounted for in such a manner, we might expect to find an increase percentage of ham as well as an increased "eye of lean". Reference to Table III shows that the carcasses in Lot III showed a slightly higher percentage of ham than the other two lots. Hence, the age factor and the biological factor of growth may be of prime importance when considering the development of muscular tissue in the animal body.

The results secured by Ellis and Zeller (46) are of special interest when viewed in the light of the results just presented. In studying the influence of high, medium and low planes of nutrition on the composition of hog carcasses, they found that the carcasses of hogs on the most restricted feeding level of corn and wheat contained a significantly greater proportion of lean meat and yielded a higher percentage of lean cuts.

The data outlined in Table III is of further importance, when it is considered that the animals in Lot III were carried on a relatively low plan of nutrition for the greater part of their growing period. These animals received about one-half of the ration that was allowed to the other two groups. Nevertheless, from a survey of the carcass measurements and grades as outlined, it may be seen that such a mode of management was not detrimental to the carcasses which resulted. This would mean, therefore, that normal bodily development must have taken place in spite of the restricted diet. The muscular development must have continued from birth to maturity to the same extent that it did in the other lots, the only difference being that it took a longer period of time to reach the final stage. Judging from these conclusions, the common practice of "growing out" pigs for a period during the summer months, followed by a rapid fattening period in the fall, should not have any detrimental effects upon the carcasses which are produced. This, of course, assumes that the animals have the inherent ability to produce good bacon carcasses.

TABLE VI: Muscle Fibre Measurements.
(Infraspinatus Muscle)

	Lot I (Inside full feed) (microns)	Lot II (Outside full feed) (microns)	Lot III (Outside half feed) (microns)
Av. Size of Muscle fibres:	67.23	65.87	66.13
Range:	73.93-60.55	72.82-61.93	72.83-60.67

The average diameters of the muscle fibres of the infraspinatus muscle are recorded, according to lots, in Table VI. These figures indicate that no appreciable difference was found in the diameters of the muscle fibres in the various lots. Within each individual muscle there was a great variation in size of the muscle fibres, which condition was found in all the samples studied. The exercise which was indulged in by Lots II and III did not have the effect of increasing the diameters of the muscle fibres within the infraspinatus muscle.

Measurements were also made of muscle fibre diameters from the same muscle, taken from the shoulders of four fattened lambs of approximately the same age as the hogs, from which samples were removed. The average diameter of these fibres was found to be 39.31 microns.

Histological Studies.

Slides were prepared from sections of the infraspinatus muscle of each carcass, in an endeavor to determine any variation which might exist between the connective tissue content of the samples. It was found on microscopic examination that there were

differences in the amount of connective tissue present in individual slides. However, this method of determination was found to be of little value, in that there was not sufficient material present in any one section to allow for a definite estimation of the connective tissue present. The error resulting from any comparisons made on this basis would be very high, due to the improbability of obtaining sections from identical portions of the samples studied. Chemical determinations of the amount of elastin and collagen present, as carried out by Mitchell, Hamilton and Haines (45) in their studies on beef would undoubtedly yield a more satisfactory result.

EXPERIMENT NO. II (Summer 1934)

A Comparison of Several Protein Supplements for Bacon Hogs, and the Effect of These upon Carcass Quality.

Pigs Used:

The same general plan of allotment that was used in Experiment I was followed in this experiment. There were five lots on test. Each lot consisted of five individuals - three of which were purebred Yorkshires, the other two being purebred Tamworths. The average age of all animals at the beginning of the experiment was 66 days; the average weight at this time was 41.2 pounds.

Method of Housing:

The five lots were housed in the shed piggery at the University Farm. They were confined in pens 10' x 12', these being equipped with cement floors and wooden sleeping platforms 7' x 8'. Straw was used for bedding.

Rations Fed:

	Beginning to 80 lbs.	80 lbs. to 130 lbs.	130 lbs. to finish
Basal Mixture	80	85	90
Protein Supplement	20	15	10

The basal mixture varied depending upon the weight of the animals, as follows:

	Beginning to 130 lbs.	130 lbs. to finish.
Barley No. 3 C.W.	40	60
Oats No. 3 C.W.	40	20
Wheat No. 3-5 N.	20	20

The protein supplement remained constant in composition for each lot, throughout the experiment. The following mixtures were used.

	Lot I	Lot II	Lot III	Lot IV	Lot V
Skim-milk Powder	95	30	-	-	-
Tankage (50% Prot.)	-	50	50	60	95
Linseed Oil Meal	-	-	20	20	-
Fish Meal	-	15	15	-	-
Soybean Meal					
Alfalfa Meal	-	-	10	15	-
Iodized Salt (.001% KI)	5	5	5	5	5

Cod liver oil was fed at the rate of 15 cc. per pig, per day until the end of the second feeding period (average weight 130 pounds).

Method of Feeding:

All lots were full fed, by hand. During the first period (up to 80 pounds) they were fed three times a day. From then on they were fed only twice daily.

The dry feed mixtures were measured out to each pen and mixed with the water allowance to form a slop.

Discussion of Ration.

The premier object of this experiment was to determine the value and effect of a number of protein supplements which may be fed to bacon hogs. The feeds used were analysed for crude protein and ash. The results of these analyses, together with the figures for the digestible crude protein as computed from Henry & Morrison's (8) tables are tabulated as follows:

	Crude Protein	*Dig. Crude Protein	Ash.
Oats	9.8	7.64	2.23
Barley	11.3	8.70	2.81
Wheat	11.3	9.04	1.73
Skim-milk powder	32.85	32.85	7.54
Fish Meal	65.68	51.23	13.19
Tankage	57.11	40.55	19.90
Alfalfa meal	14.12	**10.02	10.45
Linseed Oil Meal	39.94	33.95	4.21

* Determined on the percentages, as outlined by Henry & Morrison (8).

** Alfalfa hay - all analyses.

The nutritive ratios of the rations fed during the experiment are outlined below:

	Lot I	Lot II	Lot III	Lot IV	Lot V	Morrison Standard
First Period:	1:4.68	1:3.85	1:3.96	1:4.02	1:3.49	1:4.5
Second Period:	1:5.12	1:4.40	1:4.50	1:4.55	1:4.05	1:5.5
Third Period:	1:4.57	1:5.10	1:5.19	1:5.23	1:4.79	1:6.5

The rations fed were at all periods during the experiment, narrower than those outlined in the Morrison feeding standard. (Henry & Morrison (8)). This is particularly true in the case of the last period, during which, Morrison advises a ratio of 1:6.5 and in which the widest ratio for any of the five lots was 1:5.67. Using Morrison's figures as the optimum basis for comparison, it may be seen that all through the experiment the animals were receiving a ration which contained sufficient protein to carry on the processes of normal growth and development.

The average daily intake of digestible crude protein for each lot conforms very closely to the requirements as outlined in Morrison's Feeding Standards (8). In this, the requirement is set at about .52 pounds daily, per 100 pounds live weight. Lot I was somewhat lower than this, the intake being .44 pounds per 100 pounds live weight. This difference was in part due to the relatively low protein content of the skim-milk powder as compared to the other supplements fed, and also to the low daily feed consumption of this lot. The other four lots showed an average daily intake of crude protein of .51 pounds, .50 pounds, .48 pounds and .51 pounds, for Lots II, III, IV and V, respectively.

RESULTS OF EXPERIMENT NO. II

The average daily gains of the five lots are tabulated in the following table:

TABLE VII- Average Daily Gains.

	Lot I	Lot II	Lot III	Lot IV	Lot V
No. of Days on Expt.	115	109	112	116	114
Av. Initial Wt.(Lbs)	41.14	41.06	41.06	41.0	41.8
Av. Final Wt. (Lbs)	216.6	218.8	217.8	218.2	223.2
Av. Daily Gain (Lbs)	1.51	1.63	1.58	1.52	1.58

The figures in Table VII show the response of these groups of pigs to the various rations, as is demonstrated by the average daily gains. It may be seen that the gains in all these lots were very uniform and were also considerably higher than those secured by Sinclair and McElroy (44) in the experiments in which they studied the influence of various levels of protein on the rate of growth. The highest average daily gain reported by them was 1.27 pounds. Lot II showed a slightly higher average daily gain than did any of the other lots. However, in no case was there a sufficient difference between lots to justify any conclusion as to the utility of one supplement when compared with another.

Feed Requirements for Growth.

The average daily feed consumption and the feed requirement for 100 pounds gain in live weight, for each lot is recorded as follows:

TABLE VIII: Feed Required for Growth.
(All weights in Pounds)

Lot No.	Average Daily Feed Consumption	Feed Required for 100 pounds Gain. Grain	Protein	Total
I :	5.14	294.85	43.98	338.83
II :	5.31	283.0	43.10	326.10
III:	5.38	296.09	44.61	350.70
IV :	5.30	303.13	45.30	348.43
V :	5.47	300.84	44.92	345.76

While there is some variation between the five lots, both with regard to the daily feed consumption and also the feed required for 100 pounds gain, there is not sufficient to justify the drawing of any definite conclusions. Lot II required a slightly smaller volume of feed to put on 100 pounds gain, and as may be seen from Table VII also made a slightly higher average daily gain. On the whole, however, the figures in Tables VII and VIII, with regard to the daily gains and also the feed requirements, indicate that all of the protein supplements used were fed in sufficient quantity and had a sufficiently high biological value to carry out the normal processes of growth and fattening.

Carcass Measurements.

The measurements made on these carcasses and the standards of grading were the same as those used in the case of the pigs in Experiment I.

TABLE IX: Measurements and % of the Cuts of Carcasses.

	Lot I (Ins)	Lot II (Ins)	Lot III (Ins)	Lot IV (Ins)	Lot V (Ins)
Av. Length of Carcass :	31.25	31.70	31.55	31.1	31.85
% Shoulder of Carcass:	27.78	28.74	27.96	28.62	27.88
% Ham of Carcass:	22.98	22.64	22.92	22.70	22.76
Av. Depth of Shoulder Fat:	1.87	1.58	1.80	1.83	1.80
Av. Depth of Back Fat:	1.20	1.05	1.30	1.20	1.20
Av. Depth of Loin Fat:	1.60	1.40	1.58	1.63	1.60
Av. Min. Belly thickness:	.96	.94	.95	1.03	1.00
Av. Max. Belly thickness:	1.73	1.70	1.85	1.95	1.80

The fat measurements outlined in Table IX show that there was not a great deal of difference in the covering of fat within the five lots. Lot II showed a somewhat lower degree of finish than did any of the other four lots although the "belly" thickness did not vary to the same degree as did the covering of fat along the shoulder, back and loin. The carcasses in Lot IV carried the most finish generally although there was not a great deal of difference between this lot and lot V. It should be noted that the depth of back fat in all lots is considerably below the optimum of 1½ inches for carcasses of the "leanest" grade. Lack of fat covering on the middle portion was a characteristic of all carcasses.

Live Hog and Carcass Grades.

The gradings, according to the standards previously outlined, are as follows:

TABLE X: Carcass and "Belly" Grades.

	Lot I	Lot II	Lot III	Lot IV	Lot V
Live Grading - Selects	5	5	5	5	4
Bacons	-	-	-	-	1
Carcass Grades -					
Leanest Lean	5	4	4	4	4
Lean	-	-	-	-	-
Under finished	-	1	1	1	1
Belly Grades:					
No. Excellent	1	1	-	1	3
No. Good	4	2	4	2	1
No. Fair	-	2	1	2	1

The gradings tabulated in Table X introduce some features of the carcasses which are not apparent from the data, in Table IX. There was one animal in Lot V which graded "bacon", no intimation of this would be gained from the figures in Table IX. With reference to the carcass grades, the same condition arises. It will be noted that one carcass in all groups excepting Lot I graded "under finished". It would seem that these carcasses were placed in this class as a result of an unsatisfactory "belly" grading rather than on the basis of lack of back fat, although it will be recalled that back fat covering was decidedly marginal. Very few of the carcasses with the exception of those in Lot V secured an "excellent" belly grading. Generally speaking the "belly" grades are unsatisfactory and when this condition is considered together with the marginal covering of back fat, it becomes apparent that lack of finish was a common weakness in all lots.

Detailed Measurements.

The results of the detailed measurements made on the cross section from each carcass are reported below:

TABLE XI: Detailed Carcass Measurements.

	Lot I	Lot II	Lot III	Lot IV	Lot V
Av. Total Area of Cross Section (sq.in.)	26.58	25.51	26.66	26.99	27.55
% Lean in Cross-Section	38.41	37.75	38.64	36.27	36.19
Av. Area of "eye of lean" (Sq. in.)	4.39	4.12	4.55	4.38	4.34
Av. Area of "streak muscle (sq.in.)	1.66	1.74	1.75	1.54	1.62

The detailed measurements as made with the planimeter also indicate a similarity in all the five lots. There are slight variations in the measurements reported between the lots. Lots IV and V show a lower percentage of lean in the side than do the other three lots. This difference is not due to the size of the "eye of lean", in that, there are but very slight differences in the area of this muscle in the various lots. The streak muscle is somewhat smaller in the Lots IV and V. However, in that, Tables IX and X do not point to an extra degree of finish in these two lots as compared to the other three lots, this difference must have been largely due to the general muscling throughout the side. Lot II has the smallest eye of lean and it is of interest to note from Table IX that this lot also had a slightly smaller % of ham. However, Lot III, which shows

the largest "eye of lean" does not show the greatest percentage of ham although it is larger than in the case of Lot II. While the size of the "streak muscle" does not show any great variation it does not follow in size, the "eye of lean", at least in these lots. Lots II and III which show the greatest variation in size of "eye of lean" have practically the same size of "streak muscle". Generally speaking, no one lot deviates from the other four to a sufficient degree to warrant any assumptions concerning the effects of the rations fed upon the percentage of fat and lean in the carcasses.

EXPERIMENT III (Winter 1934-35)

The Effect of Varying the Level of Protein in the Ration on Rate of Growth and Development of Ham in the Carcass of the Bacon Hog.

Pigs Used:

There were eight animals placed in each of five lots, the general plan of allotment being on the "litter basis", in a similar manner to that described in Experiment I. All the animals used in this experiment were Tamworth - Yorkshire crosses. The average weight of all the animals at the beginning of the experiment was 47.96 pounds. The average age was 76.45 days.

Method of Housing:

The five lots were housed outside during the entire period of the experiment. The houses used were of the gable type, each being 6' x 8'. These houses were banked with straw to give additional protection. The animals had access to runways, the size of which were 26' x 80'.

Method of Allotment:

The allotments were made on the basis of the rations which were fed, and groups were arranged as follows:

		Percentage Protein		
		Start to 80 lbs. (%)	80 lbs. to 130 lbs. (%)	130 lbs. to 210 lbs. (%)
Lot I	: Cereal Ration +	4	4	4
Lot II	: " " +	8	8	8
Lot III	: " " +	12	10	8
Lot IV	: " " +	16	12	10
Lot V	: " " +	20	16	12

Feeds Used:

The cereal ration consisted of equal parts by weight of oats, barley and wheat. The oats graded 3 C.W., the barley 3 C.W., and the wheat from 5N to 6N.

The protein supplement fed was mixed in the following proportions:

Tankage	60 lbs.
Linseed Oil Meal	20 "
Alfalfa Meal	15 "
Salt	5 "
	100 "

.5 lbs. of ground limestone were added per 100 pounds of feed mixture in the case of Lot I. This brought the Ca up from about 3 grams to 8 grams daily.

Method of Feeding:

Self-feeders were used in all groups. The supplement was mixed with the cereal ration at the rates indicated above. Water was supplied twice daily to all lots.

Discussion of Ration.

The feeds used in this experiment were analyzed for crude protein and ash. The results of these analyses together with the determinations for digestible crude protein are recorded below:

	% Crude Protein	*D.C.P.	Ash.
Wheat	11.3	9.04	1.67
Oats	8.1	6.32	3.40
Barley	11.7	8.91	2.46
Tankage	46.35	32.91	25.10
Linseed Oil Meal	37.40	31.79	4.76
Alfalfa Meal	13.63	**9.68	28.77

* Computed from percentages as outlined by Henry & Morrison (8).

** Alfalfa Hay - all analyses.

The nutritive ratios of the rations fed to all lots, during the experiment were as follows:

	Lot I	Lot II	Lot III	Lot IV	Lot V	Morrison Standard.
First Period:	1:6.37	1:5.61	1:5.04	1:4.48	1:4.05	1:4.5
Second Period:	1:6.37	1:5.61	1:5.29	1:5.04	1:4.48	1:5.5
Third Period:	1:6.37	1:5.61	1:5.61	1:5.61	1:5.29	1:6.5

Discussion of Ration.

The object of blending the rations in the manner indicated was to vary the amount of protein which would be allowed in each lot. The nutritive ratios outlined above show the extent to which

that was done. Lot I received a ration, during the entire feeding period, which contained the amount of protein advised by Morrison (8) for the last fattening period, or for animals over 130 pounds in weight. For the first two periods, therefore, the pigs were, according to these standards, receiving insufficient protein. Lot II was fed a ration containing the amount of protein equivalent to that which Morrison (13) advises for animals from about 80 to 130 pounds in weight. Up to this 80 pounds of weight the animals in this lot were receiving insufficient protein and when over the 130 pound weight received an excess of protein above the requirement. Lot III received slightly less protein than is advised by Morrison. During the period up to 80 pounds the ration fed Lot IV conformed with the requirements of Morrison's Standard. From this weight on, however, there was a slight increase of protein. Lot V at all periods during the fattening process received a high protein ration.

The average daily intake of protein for each lot was as follows:

	Lot I (lbs.)	Lot II (lbs.)	Lot III (lbs)	Lot IV (lbs.)	Lot V (lbs.)
Average Daily Intake of Protein per cwt.	.41	.42	.44	.45	.51

The daily intake of protein was somewhat lower than might have been expected judging from the percentages of protein supplement which were added in the ration. This is in part due to the average daily feed consumption of each lot, but is largely due to the relatively low protein content of the supplement itself. The

tankage, as may be seen from the analyses recorded, contained 46.35% crude protein. The supplemental mixture had a crude protein content of 39.3%.

Armsby (1), in discussing the effect of limited protein brings up the question of the mineral requirements. He emphasizes the fact that when there is a low protein ration fed, the ash content is likely to be low also, and hence, the results from any experiment of this type must take this into consideration. The following table shows the average daily intake of calcium and phosphorus per cwt., in the various lots.

	Lot I (grs.)	Lot II (grs.)	Lot III (grs.)	Lot IV (grs.)	Lot V (grs.)
P.	2.90	4.08	4.59	5.22	6.89
Ca.	8.16	7.8	8.07	7.98	8.80

As was mentioned, Lot I received .5 lbs. of ground limestone, (96% $CaCO_3$) per cwt. of feed in addition to the regular ration, thus bringing the daily intake of Ca up to 8.16 grams. The calcium intake in all five lots was well over the minimum of 2.30 grams as suggested by Sinclair and McElroy (44). The phosphorus intake may also be regarded as adequate on the basis of Spildo's (47) recommendation of .35% of the ration. Judging from these, any differences which may be found to exist between these five lots would not be due to a lack of calcium or phosphorus.

RESULTS OF EXPERIMENT III.

An experiment similar to the one just outlined was carried on by Emmett and Grindley (27) at Illinois. There were in this case three groups of pigs, receiving a low, medium and high protein ration. The animals on the low protein diet received on the average of the entire feeding trial a ration which was narrower than the lot receiving the low protein in the experiment just outlined. However, in their summary, Emmett and Grindley state that all the pigs in Lot I, with the exception of one, lacked appetite. Most of them were sluggish and had locomotive difficulties. All the animals appeared unthrifty and underfed, and four died during the experiment apparently as a result of poor nourishment. Nothing like this was noticed or occurred in Lot I of the experiment being reported. The animals in this lot did not look as thrifty as those receiving a greater amount of protein. Nevertheless, they were active, had no difficulty in walking and as may be seen from one of the ensueing tables did not lack appetite.

The average daily gains of the five lots are recorded as follows:

TABLE XII: Average Daily Gains.

	Lot I	Lot II	Lot III	Lot IV	Lot V
No. of Days on Experiment	141.6	137.25	129.38	133.75	124.12
Av. Initial Wt. (lbs.)	47.79	47.75	48.62	47.71	47.94
Av. Final Wt. (lbs.)	206.62	210.25	215.12	209.75	212.25
Av. Daily Gain (lbs.)	1.12	1.18	1.29	1.21	1.32

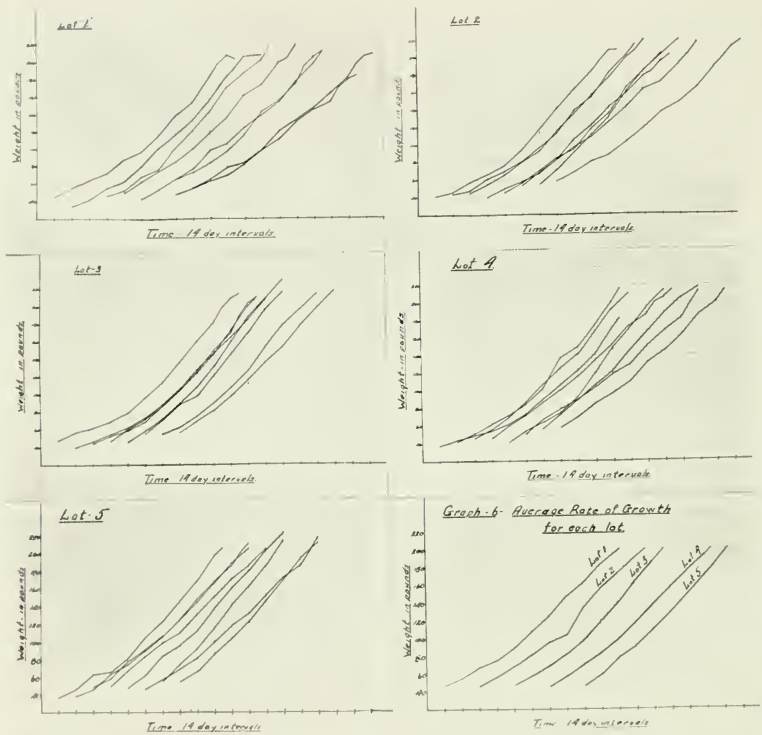


PLATE I: Showing the Rate of Growth of Individuals in the Various Lots, and the average Rate of Growth for Each Lot in Experiment III.

The average daily gains as recorded in Table XII, and the graphs shown in Plate I demonstrate the rate of growth in each lot. Lot I, which received the low protein ration, made an average daily gain of 1.12 pounds. The graphs illustrate that the rate of growth in all animals was comparatively slow, one of which attained a weight of only 182 pounds after being in the feed lot a period of 147 days. The animals in Lot II made on the average a slightly better rate of gain than did those in Lot I. The graph shows the similarity with which most of the animals in this lot responded to the ration, with respect to the rate of growth. Lot III showed a rate of growth again somewhat greater than Lot II and considerably greater than Lot I. The increase in the latter case being 15%. The average gains in Lot IV fall somewhat lower than those in Lot III. In the case of the former, however, it may be noted that one animal which was below the average weight at the beginning of the experiment, made very poor initial gains and weighed only 182 pounds at the conclusion of the 147 day feeding period. The gains of this animal are probably largely responsible for the differences in gains which occurred as between Lots III and IV. Lot V showed the best average daily gains of any of the five lots, there being an increase of 18%, as compared with Lot I. The graph demonstrates that the animals in the fifth lot made the most uniform gains, speaking of the group as a whole, and as may be seen from Table XII, reached a market weight in a shorter time than did those in any of the lots receiving less protein.

Graph No. 6 - Plate I, illustrates the average rate of growth in each lot. It shows clearly the differences in weights between lots for the same periods and also corroborates the data in Table XII demonstrating the differences in the length of time required by each lot to attain market weight.

TABLE XIII: Feed Required for Growth
(All Weights in Pounds)

	Average Daily Feed Consumption	Feed Required for 100 lbs. Gain		
		Grain	Prot. Supp.	*Total.
Lot I :	5.80	496.35	19.65	517.04
Lot II :	5.62	436.92	36.09	474.85
Lot III :	5.77	406.02	40.09	448.20
Lot IV :	5.55	404.16	51.14	458.0
Lot V :	6.04	387.54	65.30	456.3

* Salt included.

Table XIII is of interest in that it demonstrates the utility of the various rations fed, with respect to economy of utilization in increasing body weight. On comparing Lots I and II, it may be seen that an increase of 16.44 pounds of the protein supplement resulted in a saving of 59.43 pounds of the grain mixture required to increase the live weight by 100 pounds. That is, with every additional pound of protein supplement fed there was a saving of 3.6 pounds of grain. If the price of grain is set at the arbitrary figure of 1 cent per pound, the value of the supplement when fed at the rate of 8% of the ration as compared with 4%, is $36.00 a ton. Comparing in a similar manner the protein and grain requirements of Lots II and III, we find that

one p ound of protein is equivalent to 7.7 pounds of grain. That is, the supplement in the case of Lot III, as compared with Lot II, was worth $77.00 per ton. However, beyond this point the additional protein fed does not bring about any saving in the grain fed. Comparing Lots IV and III, 11.05 pounds of protein is equivalent to only 1.86 pounds of grain, similarly between Lots V and IV, 14.16 pounds of protein replaces only 16.62 pounds of grain. It would appear, therefore, that the feeding of the protein supplement at the rate of 8%, 10% and 12% as was done in the case of Lot III, had a saving effect upon the grain fed when compared with rations containing less protein. Increasing the protein supplied beyond this point, however, showed no advantage.

Using as the means of determination the total feed consumed for the entire period, it is found that Lot III consumed a ration, 9.4% of which was protein supplement. As was indicated, the average daily intake of protein was .44 pounds per 100 pounds live weight. This figure is somewhat lower than that suggested by Sinclair and McElroy (44), their figure being .55 pounds per day.

The total feed required in each of the five lots follows the same line of gradation as did the efficiency of the protein fed. The break also comes at Lot III. Lot I required considerably more of the total grain and protein mixture than did any of the other five lots. Lot III required less than any of the other groups, although there was only a slight difference between this and Lots IV and V.

Carcass Measurements.

The standard measurements and weights were taken on all carcasses, the average results of which are tabulated below:

TABLE XIV: Measurements and % of Cuts of Carcasses.

	Lot I (ins)	Lot II (ins)	Lot III (ins)	Lot IV (ins)	Lot V (ins)
Av.Length of Carcass :	30.61	30.44	30.87	30.29	30.66
% Shoulder of Carcass:	29.3	27.64	27.55	28.04	28.08
% Ham of Carcass:	23.64	23.61	23.5	23.51	23.56
Av.Depth of Shoulder fat:	1.87	1.73	1.77	1.84	1.86
Av.Depth of Back Fat:	1.21	1.03	1.08	1.16	1.11
Av.Depth of Loin Fat:	1.46	1.48	1.50	1.45	1.52
Av.Min."Belly" thickness:	.98	1.09	1.08	1.11	1.08
Av.Max. " "	1.84	1.95	1.97	1.95	1.92
Av.Carcass Wt. (cold)	155.57	155.50	160.5	158.14	156.60
Av.Dressing Percentage (cold)	74.0	74.0	74.6	74.0	73.8

It is worthy of note, in connection with the figures in Table XIV, that there was no difference in the average length of the carcasses in the five lots. Increasing the amount of protein fed to the animals did not cause an increased bodily length. There was no difference in the percentage of ham between the lots. In the case of the shoulders, however, there is a slight variation. The shoulders in Lot I were slightly more than 1% greater than in any of the other lots. In that the percentage of ham shows no decrease, this gain must have been at the expense of the middle. This being the case, it might be expected that the measurements for Lot I would indicate this. The lengths are the same in all

the groups. The only differences which exist which might influence this are the slightly lower minimum and maximum belly measurements in Lot I.

The degree of finish in all the lots is fairly uniform. Lot I showed as much covering of fat along the top line as did any of the other lots. In fact, the depth of the back fat was greater in this lot than in any of the others, particularly Lots II and III, these latter two having a marginal covering only. The back fat covering in all the lots was below the arbitrary optimum of 1½". The loin fat and shoulder fat was uniform and of sufficient depth in all the lots.

It was mentioned that the "bellies" in Lot I were lacking somewhat in thickness throughout, when compared with the other lots. However, it may be seen that while these measurements were low for this group of animals, they were nevertheless very nearly the same as the best recorded in Tables III and IX. Generally speaking, therefore, while there tended to be a lack of finish along the backs of all animals, the figures in Table XIV indicate that there was a marked uniformity between all the lots.

The average live weights at which the animals in the different lots were slaughtered were very nearly the same. The maximum difference was between Lots I and III, that being 4.98 pounds. The average dressing percentages for the five lots were within the range of 73.8% and 74.6%. This latter finding is in accordance with that of Emmett and Grindley (27). They too found very little difference in the dressing percentages of animals fed a low and a high protein diet. Had there been any marked difference in the

degree of finish in the various groups, resulting from differences in the protein-carbohydrate ratio of the rations, it would have been reasonable to expect this difference to be reflected in wider differences in the dressing percentages.

Live Hog, Carcass and Fat Grades.

The live gradings and carcass gradings were carried out according to the methods already mentioned. A fat grading was also made on all the carcasses, by the packing plant grader. It was a purely mechanical determination ascertained by pressing on the fat with the finger tip. There were two gradings - Firm and Soft. The gradings of the live animals, the carcasses and the fat are recorded as follows:

TABLE XV: Gradings of Live Animals & Carcasses.

		*Lot I	Lot II	Lot III	*Lot IV	Lot V
Live Grading -	Selects:	5	7	7	7	8
	Bacons:	2	1	1	-	-
Carcass Grading-	Leanest Lean:	6	7	8	7	8
	Underfinished:	1	1	-	-	-
Belly Grading -	No.Excellent:	1	4	4	4	6
	No.Good:	4	4	4	3	1
	No.Fair	2	-	-	-	1
Fat Grading -	No.Firm	6	7	8	7	8
	No.Soft	1	1	-	-	-

*One animal had not reached market weight at the conclusion of the experiment and was not slaughtered.

The live gradings and carcass gradings are of interest when reviewed with the data in Table XIV. Lot I contained two hogs which graded "bacon", one of these was the one which received the carcass grading of "underfinished". The same thing occurred in the case of the animal in Lot II which graded "bacon" - it too, was underfinished. This being the case, the other animals in these two lots must have had a sufficiently high degree of finish to bring the average up to within the range indicated in Table XIV. Hence, the ration fed cannot have been alone responsible for the lack of covering of fat. The animals which were underfinished were both over 200 pounds live weight when slaughtered and were not litter mates.

The "belly" gradings show some variation between the different lots. Lot II had only one "excellent" "belly", and had two which graded "fair". This feature was brought out by the measurements in Table XIV in which Lot I showed the lowest figures for both "maximum" and "minimum""belly". Lots II, III and IV were equal with respect to the grading on this portion of the carcass. Lot V, however, contained six "excellents", one "good" and one "fair". This greater proportion of higher grade "bellies" in the last lot cannot be accounted for in the results recorded of the actual "belly" measurements (Table XIV).

Firmness of Fat.

It is to be noted that the fat on one carcass in both Lots I and II graded "soft" according to the hand grading. There were no other "soft" carcasses. In order to ascertain whether the

amount of protein fed influenced the quality of the fat produced, samples of fat were removed from the same location on the back of each carcass in the various lots and a determination was made of the Iodine Number. The average results for each lot were as follows:

TABLE XVI: Iodine Numbers of Back Fat.

	Lot I	Lot II	Lot III	Lot IV	Lot V
Av. Iodine Number	61.18	59.57	62.64	62.82	61.01

From this table it may be seen that there was a slight difference in the quality of the fats in the different lots. Lot II showed the greatest degree of firmness and Lot IV was the softest. However, since there does not appear to be any consistent trend, any conclusion as to the effect of the ration upon the quality of fat produced would not be warranted. A point arises here as to the significance of the Iodine Number in connection with the commercial interpretation of soft fat. The work of Hankins and Ellis (48) is of assistance in connection with this point. As a result of extensive study, they suggest that fats of iodine number less than 63 are commercially "hard" or at least in no way objectionable to the pork trade. If we accept this figure it will be seen that the fats from all groups in this experiment average below this limit and may be regarded as satisfactory from a commercial standpoint. It is interesting to note that the two carcasses which were graded "soft" by the packing house graders had Iodine Numbers of 60.56 and 58.80 respectively.



PLATE II: Illustrating Cross Sections taken from the Carcasses of Animals in Experiment No. III.

Detailed Measurements.

A somewhat different method than that previously described was used in obtaining the tracings from the cross sections. A pane of thin ("frosted") glass was dampened and placed with the smooth side on the cut surface of the sections. Through this the details beneath were clearly visible, and due to the nature of the glass could be transcribed upon it by means of an ordinary lead pencil. This method was found to be easier and more accurate than that one used previously. Tracings were taken from this glass and area measurements made with the planimeter as before. The results of these measurements are reported in Table XVII and the sections from which tracings were made are shown opposite in Fig. 1.

TABLE XVII: Detailed Carcass Measurements.

	Lot I (sq.in)	Lot II (sq.in)	Lot III (sq.in)	Lot IV (sq.in)	Lot V (sq.in)
Av.Total area of cross sections:	26.14	27.01	26.23	26.81	26.00
% Lean in cross sections:	39.45	43.04	37.66	40.92	40.09
Av.Area of "eye of lean":	4.43	4.90	4.19	4.56	4.50
Av.Area of "streak muscle":	1.73	1.97	1.72	1.89	1.80

Upon reviewing the data outlined in Table XVII, it may be seen that some variation did occur between the various lots with regard to the percentages and measurements tabulated. The percentage of lean is higher in Lot II than it is in Lot I. As might be expected, the same thing is true of the area of the "eye of lean" and the "streak muscle". However, the figures for

Lot III show that it was lower again than Lot I, and those for Lots IV and V are approximately the same as those for Lot I. Hence, it may be seen that there is no progressive increase in the percentage of lean in the carcass as the level of protein was increased in the rations of the various lots. A review of the data on the individual sections from the animals in Lot III shows that there were a number which had a percentage of lean that was low in comparison to the sections from the other lots. While this variation exists between lots, nevertheless, as has been mentioned, there is no evidence to show that increasing the amount of protein fed had any tendency to increase the amount of lean meat in the carcass. Comparing the percentage of lean meat in the sections from Lot I, which received a low protein ration and those from Lot V which received a greater amount of protein, it is apparent that there was an equal development of muscling in both lots. Hence, the biological processes which were involved in the development of the lean meat were carried on to the same degree on the low protein and the high protein ration. These figures show, therefore, that insofar as the development of lean meat is concerned there is no advantage in feeding protein at as a high a level as was done in the case of Lot V.

The carrying out of balance experiments in connection with the feeding trials would undoubtedly have been of value in determining the degree to which protein was utilized in the various groups. It would appear that when the protein was fed at the higher levels a percentage must have been deaminized and utilized for purposes of energy or fat production.

A Study of the Carcass Data on a Litter Basis.

A rather serious difficulty experienced in arriving at conclusions from data of this type is the variation which exists between individuals within lots. The range for any one measurement is very wide within lots. These differences cannot be explained on the basis of management practices, at least to the extent to which they may be controlled.

It has been mentioned previously that the greatest possible care was exercised when grouping the animals in the three experiments which have been reviewed. This was done on what has been designated as the "litter basis". This simply means that all the animals in one lot were, as far as possible, litter mates of the animals in the other lots on the same experiment. This is a plan commonly followed in swine experiments and which has been discussed recently by Dunlop (49) in the light of Cambridge experiments. This method of allotment is followed in an endeavor to reduce as far as possible the degree of variability between lots and is based upon the assumption that animals of the same breeding and thus of the same genetic make-up will react uniformly to the particular experimental condition which may be imposed. With this in mind it was thought advisable to study as far as was possible the data based on a litter analysis. In this case, therefore, the animals in any one group would have been subject to different feeding or management conditions but would be of the same genetic make-up. Thus, the interpretation of the results would be based upon the similarity or variability which occurred

within the litters.

The litters in Experiment II lend themselves more readily to a survey of this kind than do those in the other two experiments in that the rations fed were very similar in nutritive value. It may be pointed out here, however, that any results indicated will only be suggestive since the number of animals in the litters under consideration are only five in number.

Carcass Measurements by Litters.

The averages of the carcass measurements for the five litters which made up Experiment II are as follows:

Table XVIII: Carcass Percentages and Measurements.

	Litter No. I (ins.)	Litter No. II (ins.)	Litter No. III (ins.)	Litter NO. IV (ins.)	Litter No. V (ins.)
Av. Length of Carcass :	31.7	31.4	31.95	30.85	31.55
% Shoulder of Carcass :	27.88	27.8	28.18	28.10	29.02
% Ham of Carcass :	22.38	22.1	23.22	22.5	23.8
Av.Depth Shoulder Fat :	1.75	1.875	1.725	1.95	1.575
Av.Depth Back Fat :	1.20	1.275	1.075	1.35	1.00
Av.Depth Loin Fat :	1.60	1.525	1.575	1.70	1.40
Av.Min.Belly Thickness :	1.03	1.00	.95	1.04	.85
Av.Max.Belly Thickness :	1.85	1.85	1.725	1.85	1.70

Litters II and III were purebred Tamworths, while the other three were purebred Yorkshires.

The average live weights at which all the litters were marketed ranged from 215.2 to 222.4 pounds. Having this in mind and referring to the data in Table XVIII, it may be seen that some of these litters did not possess the same inherent

tendency to develop fat, or lean, as the case may be,in a given period as did other litters. This is particularly true in the case of Litter V. It may be seen in connection with this group that not only were the fat measurements along the back considerably below those in any of the other litters, but the "belly" thickness was also less than in any of the other groups. Litter III also showed a tendency to lack finish, specially along the back, and a general thinness of "belly". Litter IV had the highest degree of finish and also the thickest "belly".

There is very little difference in the length of carcasses which were produced from the different litters. The percentages of ham and shoulder also showed only a slight variation. Lot V had a comparably low percentage of middle piece and Lot III whowed the same tendency. It is interesting to note the relation which exists in these two litters between the percentage middle and the minimum and maximum "belly" measurements.

When the figures in Table XVIII are compared with those in Table IX, the differences between litters are more clearly defined. From the standpoint of length of carcass all the animals must have been very similar in that the degree of difference between these measurements as recorded in the two tables is very slight. The same thing is true with respect to the percentages of shoulder and ham, although for both these figures Litter V is somewhat above the general trend. With respect to the fat measurements, however, there is a greater variation. For example, there is no lot recorded in Table IX which showed the covering of fat that was evident for Litter IV. This is the outstanding feature in comparing these

two tables. It may be seen, however, that the lack of "belly" thickness for all the lots in Table IX was due to the presence of the animals from Litter V and to a lesser degree those from Litter III.

The degree of variability between animals, whether the data were considered on the experimental lot basis or on the litter basis, was equally great. Such factors as the length of side showed differences as great as 2" in both these cases. The fat measurements and "belly" measurements also showed great variations between individuals. However, as may be seen from Table XVIII, there was a tendency, regardless of the variations, for the litter mates to show either a higher or a lower degree of finish as a whole when compared with the same animals allotted on the basis of the experimental grouping.

Detailed Carcass Measurements by Litters.

The results of the detailed measurements for the litters are as follows:

TABLE XIX: Detailed Measurements of Cross Sections.

	Litter No. I (sq.in.)	Litter No. II (sq.in)	Litter No.III (sq.in)	Litter No.IV (sq.in)	Litter No. V (sq.in)
Av. Total Area of cross section:	27.85	28.21	24.52	28.36	24.35
% Lean in Cross section:	33.25	35.76	40.12	32.35	45.78
Av.Area "eye of lean" :	3.84	4.36	4.42	4.15	5.00
Av. Area "streak muscle":	1.55	1.60	1.71	1.69	1.75

The figures in the above table show trends similar to those in Table XVIII. It may be seen that Litters III and V showed

definitely a higher percentage of lean than did any of the other litters. This corroborates the findings reported in Table XVIII with reference to the lack of fat covering in these two lots. Litter IV, having the lowest percentage of lean, would have the highest degree of finish, which was also brought out in the remarks in connection with the figures in Table XVIII. It may be seen that the "eye of lean" and also the "streak muscle" were larger in the case of Litter V. This would in part account for the high percentage of lean in the entire section.

On comparing the figures in Table XIX and Table XI, it is again apparent that the tendency is for the extremes of these measurements to fall within a litter. This applies to the total area of the cross sections, the percentage of lean, the size of the "eye of lean" and in a lesser degree, to the area of the "streak muscle".

The differences between individuals for the total area of the sections and the other detailed carcass measurements were large. However, the variations between the litter mates was not as great as was the variation between individuals in the experimental lots. The range between the maximum and minimum figures for the detailed measurements was much the same as for all the litters.

It has been mentioned that Experiment II lent itself to an analysis of this type more readily than did either of the other two experiments discussed. However, a survey of the litter data from Experiments I and III indicates that the same trends were followed as those shown in from Experiment II. There was

practically as great a variation between individuals in one litter as there was between individuals in any one lot. However, the tendency was for litter-mates to show a similarity with respect to what may be regarded as an inherent potentiality in the matter of putting on fat during a given stage of growth or to the development of a large "eye of lean".

The analysis of figures for carcass measurements with the object of determining any tendency toward similarity between litter-mates is of considerable importance. This is particularly true in view of the ever increasing use of the "litter-grouping" method of making up experimental lots. If it can be shown that certain strains have the ability to produce carcasses containing an optimum amount of lean and fat, a system of inbreeding could be developed which should produce animals having a sufficiently high degree of similarity with respect to this feature of the carcass quality, to reduce the variability to a minimum. Experiments having to do with the influence of rations and management practices upon carcass quality could then be conducted on a much more satisfactory basis. Such findings would also be of value to the ordinary swine raiser. With a knowledge of this, the development of strains could be followed, the result of which would be the production of carcasses of a uniformity in type and quality, the like of which cannot be produced at present with the limited knowledge available of carcass and litter relationships.

A Further Study of Carcass Data.

One of the objects of this thesis as was outlined previously was to determine mathematically whether there were any correlations between some of the more important features involved in carcass quality. Findings of this type would be of value not only to the buyer and processor of pork products but also to the producer and breeder. There are certain carcass and body characteristics which are readily assessable while the animal is alive. Length is an example of one of these. While it is not possible to determine definitely the length of an animal on the hoof, nevertheless a comparative judgement can quite readily be made. The same thing is true of the comparative proportions of the hams and shoulders. There are some more or less intrinsic features, however, such as the size of the "eye of lean" or the proportion of lean meat to fat which cannot be determined by a visual inspection. If, therefore, some correlation could be found between these two types of carcass qualifications, for example, length and the percentage of ham or the thickness of "belly"; the gradings of the animals would be more indicative of the general carcass quality than is the case when just a few of the more important apparent features are taken into consideration.

In connection with these carcass measurements and percentages, the averages obtained from a large number of carcasses are worthy of special note. It might be mentioned that a number of these were obtained from Advanced Registry reports on pigs under-

going test at the Dominion Experimental Station, Lacombe, Alberta, and at the University of Alberta. These pigs were undoubtedly of somewhat better breeding and of higher quality than the average commercial animals. The rest of the figures were obtained from carcasses of animals fed on experiments at the University of Alberta during the summer of 1934 and the winter of 1934-35, a large number of which were included in the experiments previously outlined.

TABLE XX: *Carcass Measurements.

Length of Carcass	:	30.8 in.
Depth of Shoulder Fat	:	1.825 in.
Depth of Back Fat	:	1.15 in.
Depth of Loin Fat	:	1.49 in.
% Ham of Carcass	:	23.94
% Middle of Carcass	:	47.52
% Shoulder of Carcass	:	28.54

* Average measurements from 350 carcasses.

The average figures outlined in Table XX, in that they are comprised of a large number of individual determinations, show the general trend of these carcass measurements. It may be seen that the fat covering over the shoulder is on the average high and when it is compared with the other measurements of fat along the back ("loin fat" and "back fat") is somewhat out of line, thus indicating a lack of uniformity of covering. It would seem that the ideal of a uniformity of fat covering from shoulder to loin is difficult to attain.

One point of particular interest in connection with Table XX is the relationship between the percentage of ham and the percentage

of shoulder. Hammond's (13) theory on development has been mentioned previously but it does not appear from the data reported that the shoulders and hams could make up equal proportions of the carcass, in that the percentage of ham is 4.6% greater than the percentage of shoulder. In no case was there a carcass in which the hams and shoulders were equal in proportion. Hence, the ideal proportions, of 50% middle, 25% shoulder and 25% ham, on the basis of the cutting practice followed in the Packing Plants, would appear to be out of line with the normal anatomical development of the bacon hog, at least as it has been bred and reared up to the present time. Further averages have been obtained on the more detailed features of the carcasses.

TABLE XXI:*Detailed Carcass Measurements.

Maximum "belly" Thickness (in.)	1.877	± .0301
Minimum "belly" Thickness (in.)	1.03	± .0364
Av. Area of Cross Sections(sq.in)	26.44	
Av. Area of "eye of lean" (sq.in)	4.43	
Av. % of lean in Cross Section	37.60	±1.0415
Av. % of "eye of lean" in Cross section:	16.46	± .3014

*Average measurements from 106 carcasses.

Judging from the average minimum "belly" measurements in Table XXI, it would appear that a measurement of 1 inch may be regarded as a satisfactory thickness of "belly" at the point where this measurement was taken.

The percentage of lean in the cross sections averaged 37.6 percentage. This figure may be compared with those obtained by Mitchell and Hamilton (50) in their work at Illinois. They made

determinations of the percentages of lean meat, fat, skin and bone in the carcasses of animals which had been subject to various methods of feeding. The figures they give for the percentage of lean in the entire carcass range from 42.3% in a "very chuffy" or short overfinished animal to 47.1% in the case of the longer and thinner hogs. These figures are somewhat above those obtained for the sections through the middle. This is easily understood, however, in that, with the exception of the "eye of lean", which makes up only 16.46% of the whole, there are very few large solid masses of lean meat in the sections from the middle. The individual muscles are interspersed with layers of fat, a condition which is not found to the same extent in any other part of the body and which is no doubt largely responsible for the differences mentioned.

A number of correlations have been worked out from the data obtained on the carcasses of the animals in the three experiments which were reviewed. The correlations between the percentage of total lean meat in the sections studied and some of the main carcass measurements are tabulated below.

TABLE XXII: Correlations between the % Total Lean and Carcass Measurements.

Length of the carcass	:	+ .5515 ± .0606
Depth of Shoulder Fat	:	- .3689 ± .0751
Depth of Back Fat	:	- .2981 ± .0793
Depth of Loin Fat	:	- .2163 ± .0831
Minimum "belly" thickness	:	- .4751 ± .0674
Maximum "belly" thickness	:	- .1926 ± .0838
% Ham of entire carcass	:	+ .8802 ± .1961
% Shoulder of entire carcass	:	- .6291 ± .0526

From the above table it is to be noted that there is a slight positive correlation between the length of the carcass and the percentage of lean meat in the sections that were studied. This means that the longer pigs had a tendency to show a greater amount of lean meat at that point of the carcass where the detailed measurements were made. In connection with the minimum "belly" measurement, there is a slight tendency for a negative correlation between this feature and the % of lean in the cross sections. This would indicate that those carcasses having the highest percentage of lean at the point determined also tended to have the thickest flank. One very important feature in connection with Table XXII is the definitely positive correlation which exists between the percentage of lean meat and the percentage of ham. Therefore, as the ham tended to increase in size when compared to the rest of the body, the proportion of lean meat or muscle in the side would tend also to increase. The opposite occurs in the case of the shoulder. As the percentage of lean meat increases, the size of the shoulder decreases. Judging from these relations, we should expect to find a negative correlation

between the percentage of ham and the percentage of shoulder at this point. However, the results conflict for there is a positive correlation of .7495 ± .0381 between the percentage shoulder and the percentage ham.

The relation that the proportions of the ends of the carcass bear to one another is of great importance. It again brings up this question of the growth of the animal body and the line along which this development takes place. If there is a positive correlation between the proportions of the ham and the shoulder, it would mean that these two increase at the expense of the middle piece of the carcass. In that, as it has been suggested previously, this latter portion is the more valuable half of the side, a relation of this kind is of great economic value to the producer and processor. If, however, as is indicated by the correlations of the percentagetotal lean and the percentages of the ham and shoulder, the proportion of the shoulder decreases as the ham increases, there is very good evidence in support of Hammond's (13) theory on bodily development. This latter would also intimate that at some period during the growth of the animal, providing this does not cease too early in life, there is a time when the shoulders and hams are equal or very nearly equal in proportion. However, as has been indicated, the data obtained here is contradictory on this point and must be verified either one way or the other before any definite statement can be made upon this point. It may be seen from table XXII that there is no relation between the covering of fat over the back and the percentage of lean meat in the side.

Correlations have been computed on the basis of the percentage "eye of lean" and the other carcass measurements. They are as follows:

TABLE XXIII: Correlations Between the Percentage "Eye of Lean" and Carcass Measurements.

Length of Carcass	: +.2179 ± .0829
Depth of Shoulder Fat	: -.7439 ± .0389
Depth of Back Fat	: -.6031 ± .0554
Depth of Loin Fat	: -.3418 ± .0769
% Shoulder of Entire Carcass	: -.2657 ± .0193
% Ham of Entire Carcass:	: +.9523 ± .0904

There is a negative correlation between the percentage of the "eye of lean" and the shoulder fat, and also the depth of back fat. This is a finding which is difficult to explain on any basis of growth and development as it has been discussed up to the present time. There appears to be no reason why there should be any relationship between these measurements.

The most striking and outstanding figure in Table XXIII is the high positive correlation between the percentage of "eye of lean" and the percentage of ham. In that the "eye of lean" makes up a large proportion of the total lean in the cross sections, this figure is in line with that in Table XXII which shows a positive correlation between the percentage total lean and the percentage ham. This means, therefore, that the larger percentage of ham is associated with the larger percentage of "eye of lean" in the cross sections. Such an arrangement seems reasonable on the basis of the anatomy of the animal, since the longissimus dorsi muscle, or the "eye of lean" is the only large muscle

which connects the hind quarters with the fore-quarters and the central portion of the animal body. This relation between these two features of the carcass quality is, therefore, of interest not only from the standpoint of the growth of the animal but also from the point of view of graders and those interested in the value of the carcass as a whole.

It is interesting to note that there is no significant negative correlation between the percentage "eye of lean" and the percentage shoulder. This would intimate that the relation between the percentage of this shoulder cut and the percentage of total lean as indicated in Table XXII is not as significant as the figures would tend to indicate.

Since length is a factor of carcass quality which can be estimated to a comparative degree on visual inspection, any correlation between this anatomical aspect and other features of carcass quality would be of interest. The following table shows the figures obtained from an analysis of this type:

TABLE XXIV: Correlations Between Length and Other Carcass Measurements.

Depth of Back Fat	: -.0945 ± .0793
Minimum "Belly" thickness	: +.0922 ± .0863
Maximum "belly" thickness	: +.0622 ± .0866
Percentage Ham	: +.2910 ± .0797
Percentage Shoulder	+.1881 ± .0839

There is no correlation between the length of the carcass and the features of the carcass recorded in Table XXIV. Hence, statements to the effect that the longer pig shows a thinner

"belly" or a lower percentage of ham or shoulder, or a lack of fat on the back would scarcely seem to be justified in the light of the lack of correlation between the figures outlined in the above table.

SUMMARY OF EXPERIMENTS & ANALYSES.

The first experiment of the series which has been discussed was initiated to determine whether exercise and the porcine habit of rooting had any effect upon the development of the shoulder of the bacon hog, either with reference to the relative proportions of this part of the carcass, or to the size of the muscle fibres within the infraspinatus muscle in the shoulder. Due to the method of planning the experiment, it was possible to determine the effect of inside full feeding, outside full feeding and outside limited feeding upon the rate of gains and feed requirements under conditions of this kind, and also the effect that these different modes of management had upon the quality of the carcass produced.

It was found that exercise did not increase the percentage of shoulder in the bacon hog, nor did it have the effect of increasing the diameter of the muscle fibres within the infraspinatus muscle. The average daily gains in the three lots used showed a marked gradation. Those fed inside on a full ration made an average daily gain of 1.53 pounds, those on pasture and full feed gained 1.44 pounds per day, and those fed on pasture and half feed gained 1.01 pounds per day. This latter lot was

put on full feed for the last six weeks of the experiment but required 167 days to reach market weight as compared to 111 and 119.5 days in the other two lots. The feed required to put on 100 pounds of gain was the lowest in the case of the lot fed inside, and was practically the same for the other two lots. The results obtained indicated that the only difference between feeding full and half feed on pasture with a final finishing period for the latter group was that those receiving only half feed required a longer time to attain market weight.

The results obtained in the carcass quality determinations showed that the carcasses resulting from all three lots were of very high quality, those fed inside on full feed having a slightly higher degree of finish than those from the lots fed on pasture. There was no difference in the average lengths of the carcasses within the three lots. The percentage of lean in the cross section of the side and also the area of the "eye of lean" was greatest in the case of the lot fed outside on half feed which indicates that the muscle development continues even when the feed consumed is below that required for normal growth.

It was found from histological studies that it was impossible to compare the amounts of connective tissue in sections of the size used in making ordinary microscopic examinations. Chemical determinations are advised as the most accurate means of comparing tissues of this type in sections of meat.

The object of the second experiment was to determine the effect of feeding a number of different protein supplements upon

the rate of growth of fattening pigs and also upon the quality of the carcasses which resulted. The feeds used were mixed and fed in proportions which would conform with the requirements set out in Morrison's Feeding Standards (8).

The average daily gains for all the five lots fed on this experiment were uniform and indicated a growth rate for the feeding period. There was only a slight difference in the feed required to make a hundred pounds of gain, indicating that all of the supplements fed were sufficient in quantity and quality. The data collected from the measurements of the carcasses of these animals showed that there was a high degree of uniformity between all the lots in respect to the carcass quality. It was noted, however, that in all the lots there was a lack of finish along the back and a thinness of "belly" in the flank region. Therefore, while the data indicated that the supplements used were of equal value when compared upon the basis of the rates of growth which resulted, or upon the basis of the quality of the carcasses which were produced, nevertheless, in all the lots there tended to be a lack of finish and thickness of "belly" in the carcasses which would designate them as tending toward "underfinished".

The third experiment of the series was drawn up with the object in view of determining whether feeding varying amounts of protein in the ration would have any effect upon the quantity of lean meat in the carcass, and upon the quality of the carcasses generally. The rate of growth and feed requirements were also

noted. The experiment comprised five lots of eight animals, each lot receiving a different level of protein in the diet. One lot received a ration, which according to the common standards was low in protein, while another was fed a high protein diet; the other three lots were fed rations the amount of protein in which was intermediary between the two extremes.

The rate of growth determined by the average daily gains showed a gradual increase from the lot receiving the low, or 4% protein level, to the lot receiving protein fed at the levels of 12%, 10% and 8%. Beyond this point, however, any additional protein fed did not produce any appreciable increase in the rate of growth. The data for the feed required for growth showed that with respect to this phase of the question the point of optimum returns was also in the lot which received the 12%, 10% and 8% of protein. Those animals receiving less protein than that amount required a larger amount of the feed mixture to put on 100 pounds gain but those which were fed diets containing more protein than the amount cited did not show any advantage in the utilization of feed.

The degree of finish on the carcasses was fairly uniform for all the lots. It was noted that the lot which received the low protein ration with a wide nutritive ratio, did not carry a thicker covering of fat over the back than was found to be the case in any of the other lots. The back fat in all the five lots was found to measure less than $1\frac{1}{2}$". There was no difference in the average length of the carcasses in the five lots, hence, increasing the amount of protein fed did not cause any increase in

in length. There was no difference in the average dressing percentage between the various lots. The results of Iodine Number determinations which were made on the back fat of all the carcasses showed that there was no material difference in the degree of firmness of the fat produced in the various lots.

The detailed measurements made on the sections taken from the middle of the carcasses showed some degree of variation between lots. However, these differences were not such as to indicate that the amount of protein fed had any effect upon the amount of lean meat produced in the side of the bacon hog.

In view of the variation which was found to exist between individuals in the same lot, with respect to the measurements used in determining carcass quality, it was thought advisable to analyse some of the data obtained, on the litter basis. The carcass measurements procured from the animals in Experiment II were used to make this analysis. It was found that the degree of variability was equally great irrespective of whether the data was considered on the experimental lot, or the litter basis. However, there was a tendency for the animals in one litter to show either a higher or a lower degree of finish when compared with the same animals in experimental lots.

Correlations were computed between a number of the more important factors involved in carcass quality. The results obtained showed that there was no correlation between the length of the carcass and such factors as, thickness of "belly", depth of back fat or percentage of ham or shoulder. There was a positive correlation, however, between the percentage of the "eye of lean", and the

percentage of ham and an inverse correlation between the percentage "eye of lean" and shoulder and back fat. There was also found to be a positive correlation between the percentage total lean and the percentage of ham. In connection with the general proportions of the carcasses studied, it was found that there was a positive correlation between the percentage of shoulder and the percentage of ham.

CONCLUSIONS.

The following conclusions may be drawn from the results of the experiments and analyses which have been reviewed in this thesis:

1. Exercise and "rooting" does not tend to increase the proportion of the shoulders in relation to the rest of the carcass of the bacon hog.

2. The diameters of the muscle fibres in the "infraspinatus" muscle are not increased as a result of the increased exercise taken by the animal.

3. The carcasses of bacon hogs which received a limited grain allowance with pasture for a period of 120 days, following which they received a full feed allowance until they attained market weight, were of as high a quality and contained a higher percentage of lean meat in the side than did the animals which received a full feed allowance, with or without pasture, during the entire feeding period. However, it took the former approximately two months longer to attain a marketable weight and finish.

4. Limiting the grain ration during a period of 120 days and thus providing for a "growing period" did not result in the production of carcasses showing greater length.

5. The feeding of the protein supplements outlined in Experiment II resulted in a high and uniform rate of growth in all lots.

6. The carcasses resulting from the animals receiving the various protein supplements fed in the second experiment were all very uniform with respect to quality but on the average lacked finish along the back.

7. The rate of growth of hogs receiving rations containing varying levels of protein showed a gradual increase up to the point where protein was fed at the average levels of 10%. Feeding protein in excess of this proportion did not result in any further increase in the rate of growth.

8. Feeding protein at the average rate of 10% of the ration resulted in a saving of the feed required for gains when compared with rations containing a lower percentage of protein. The addition of protein beyond this point did not result in any further decreasing of the feed requirements.

9. Feeding protein at varying levels to the growing bacon hog does not vary the percentage of lean meat which is produced in the carcass, at least insofar as the sections on which measurements were made may be taken to represent the proportions of lean meat in the carcass as a whole.

10. The length of the carcass is not affected by the percentage of protein which is fed in the diet.

11. The type of the ration fed, with respect to the amount of protein it contains, does not affect materially the firmness of the fat laid down along the back.

12. The average measurements of the carcass as computed from 350 individuals were - length 30.8 inches; depth of shoulder fat, 1.825 inches; depth of back fat, 1.15 inches; depth of loin fat, 1.49 inches; % ham, 23.94; % middle, 47.52 and % shoulder, 28.54.

13. There is a great variation between litter mates with respect to the percentages and measurements of the carcasses. However, there is a tendency for the animals in one litter to show either a higher or a lower degree of finish when compared with the same animals placed in experimental lots.

14. There is no correlation between the length of the carcass and the percentage of shoulder or ham, the thickness of the "belly" or the depth of the back fat.

15. There is a positive correlation between the percentage "eye of lean" as well as % total lean, and the percentage of ham, thus indicating that the size of the ham may be regarded as a criteria as to the percentage of lean in the carcass.

16. An inverse correlation exists between the percentage "eye of lean" and the depth of back fat and shoulder fat.

17. There is a correlation of +.7495 ±.0381 between the percentage ham of the carcass and the percentage shoulder.

BIBLIOGRAPHY

1. ARMSBY, H.P: The Nutrition of Farm Animals. MacMillan Co., New York, 1917.

2. McCOLLUM, E.V: The Newer Knowledge of Nutrition, 2nd Edition, MacMillan Co., New York, 1923.

3. STARLING, E.H: Principles of Human Physiology, 3rd Edition, Lea & Febiger, Philadephia, 1920.

4. CAMERON, A.T: Textbook of Biochemistry, 3rd Edition, J. & A. Churchill, London, 1932.

5. LUSK, G: The Basis of Nutrition. Yale Univ. Press, New Haven, 1915.

6. CHITTENDEN, R.H: The Nutrition of Man. Fredrick Stokes Company, New York, 1907.

7. SMITH, F: A Manual of Veterinary Physiology. 5th Edition, Alex. Eger, Chicago, 1921.

8. HENRY & MORRISON: Feeds and Feeding, 18th Edition, Henry-Morrison Co., Madison, Wis., 1923.

9. BODANSKY, M: Introduction to Physiological Chemistry, John Wiley & Sons, Inc., New York, 1927.

10. MENDEL, L.B: Nutrition - The Chemistry of Life. Yale Univ. Press, New Haven, 1923.

12. DIETRICH, Wm: Swine, - Breeding, Feeding and Management, Sanders Publishing Co., Chicago, 1912.

13. HAMMOND, JOHN: Growth and Development of Mutton Qualities in the Sheep. Oliver & Boyd, Edinburgh, 1932.

14. CHANEY & AHLBORN: Nutrition. Houghton Mifflin Co., New York, 1934.

15. HENRY, W.A: Wisconsin Sta. Report, No. 7, 1890.

16. SHAW, T.J: Jour. Min. Agric., 35, 1928.

17. SWANSON, C.O: Effect of Rations on the Development of Pigs. Jour. Agric. Res. XXI, p.279-341, 1921.

18. CURTIS & CRAIG: Iowa Sta. Bul. 48, 1900.

19. SHELDON, G.M: Kansas Sta. Bul. No. 9, p.107-119, 1889.

20. DUGGAR, J.F: Alabama College Station Bul. No. 82, p. 107-119, 1897.

21. FORBES , E.B. et al: Ohio State Bul. 283, p.111-152, 1915.

22. JOSEPH, W.E: Illinois Sta. Bul. 173, p.289-317, 1914.

23. ROTHWELL, G.B: The Influence of Feeds and Feeding on the type of Market Hogs. Agric. Gaz. of Canada, March - April, 1923.

24. BOETHGE, G: Nutritional Abstracts & Reviews, Vol. II, No. 3, p.637-8, 1933.

25. SCHUTTE & MURRAY: Nutritional Abstracts & Reviews, Vol. I, No. 3, 558, 1932.

26. INDIANA STATION REPORT, 1927.

27. EMMETT & GRINDLEY: A Study of the Development of Growing Pigs. Ill. Agric. Exp. Sta. Report No. 168, 1914.

28. KULBS & BERBERICH: Investigations on the Influence of Exercise on the Development and Composition of Internal Organs. Abstracted from Exp. Sta. Record, Vol. XXVIII, 272, 1913.

33. MORPURGO: Quoted from Hammond (13) page 490.

34. HALBON: Quoted from Hammond (13) p. 490

35. SCHIEFFERDECKER: Quoted from Hammond (13) p.490

36. HOUCK: Quoted from Hammond (13) p.490

37. SCHAFER: Quoted from Hammond (13) p.490

38. PRENANT: Quoted from Hammond (13) p.490

39. LEIGHTON & DOUGLAS: Quoted from Hammond (13) p.537

40. ROBERTSON & BAKER: Histological Differences in the Muscles of Full, Half and Rough Fed Steers. Missouri Exp. Sta. Res. Bul. 200, 1933.

41 ISAAK: Quoted from Hammond (13) p.535.

42. SINCLAIR & SACKVILLE: A Study of Some Problems in Bacon Hog Production, University of Alberta Bul. 15, 1927.

44. SINCLAIR & McELROY: The Addition of Protein & Calcium to a Ration of Small Grains for Growing Pigs. Scientific Agriculture Vol. XV. No. 7, 1935.

45. MITCHELL, HAMILTON & HAINES: Some Factors Affecting the Connective Tissue Content of Beef Muscle. Jour. of Nutrition, Vol. I, No. 2, 1928.

46. ELLIS & ZELLER: Effect of Quality and Kind of Feed on Economy of Gains and Body Composition of Hogs. U.S.D.A. Tech. Bul. 413, 1934.

47. SPILDO, L.S: Quoted from Sinclair & McElroy, (44) 448.

48. HANKINS & ELLIS: Some Results of Soft Pork Investigations. U.S.D.A. Bul. 1407, 1926.

49. DUNLOP, G: Methods of Experimentation in Animal Nutrition. Jour. Agric. Sci. Vol. XXIII, Part IV, 1933.

50. MITCHELL & HAMILTON: Swine Type Studies. Ill. Exp. Sta. Bul. 323, 1929.

53. HAMMOND, J: Problems of Feeding and Management in Pig Production. The Veterinary Journal, Vol. XC. No. 3, 98-102.

B29743